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Research Article

Food Security in Pakistan and Need for Public Policy Adjustments

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Abstract

Sustainable food and nutrition security solutions demand integration and alignment in public policies, particularly in the post-COVID-19 scenarios. The introduction of integrated public policies to address the food and nutrition needs in Pakistan is an immediate requirement. This study has applied the Foster, Greer and Thorbecke (FGT) index to estimate food and nutrition security dimensions through primary and secondary data. This analysis reveals that food utilization and sustainability have destabilized and deteriorated in Pakistan in recent years. It shows that non-farmers are more food insecure (8 percent) than farmers (4 percent) and this ratio has increased from 2008 to 2018. Food insecurity in terms of food availability and food accessibility has decreased. A holistic approach in public policies toward food security is the clarion call of the time. Therefore, the paper recommends that more focus should be given to knowledge transmission about dietary diversity, provision of quality education, and health facilities in the formulation as well as execution of food security policies.

Keywords: Food Security, Health System, Sustainable Solutions, Food Accessibility, Dietary Diversity, Public Policies.

Introduction

The definition of food security developed by the Food and Agriculture Organization (FAO) in 1996 focused on food availability, food accessibility and food utilization.[1] In 2009, food sustainability was added as the fourth

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dimension.[2] The global concerns have further shaped into food and nutrition security (FNS), which is being steered globally under the United Nations System Standing Committee on Nutrition (UNSCN). FNS is achieved when everyone has sustainable access to sufficient, safe, and nutritious food without any physical, social, or economic barriers to meet dietary needs and food preferences in an environment of adequate health, sanitation, and care.[3] The FNS ensures that everyone gets adequate quantity and quality of diversified, varietal, safer and nutritious contents to fulfill their dietary requirements according to their respective food preferences in an environment that helps healthy and active life.[4] Food system is based on elements and activities including the production, treatment or processing, distribution and consumption of food, and the sustainability of FNS relates to each of them. Being a vital part of the right to life, food security is a key concern for the UN, its agencies, programs, funds, and initiatives and is demonstrated through various binding and non-binding instruments, including the Universal Declaration of Human Rights (UDHR), the International Covenant on Economic, Social, and Cultural Rights (ICESCR), and the specific treaties for refugees, children, women and the persons with disabilities. The Millennium Development Goals (MDG4, MDG5, MDG6) and Sustainable Development Goals (12 out of 17) too are connected to food security. Pakistan has taken legislative measures regarding Sustainable Development Goals SDG4 (quality education), SDG8 (decent work and economic growth) and SDG16 (peace, justice, and strong institution). The efforts have been implemented through seven SDG Support Units at provincial and federal levels.[5]

Recently, the Coronavirus pandemic (COVID-19) posed a huge challenge to humanity by causing economic disruption and reducing global annual Gross Domestic Product (GDP) growth.[6] The socioeconomic crisis caused by COVID-19 jeopardized the whole chain of food supply. At the social level, the ratio of the individuals who donated food declined sharply in some countries because households' priority of food supply changed to retaining food security for themselves.[7] Health has always remained a serious concern but COVID-19 has changed the world not only by infecting scores of people around the world but also by jeopardizing the access to food and the means to it including education, employment, social interactions, and mobility.[8] A public policy is supposed to adapt to the rising challenges and ensure preparedness through the development of structures, schemes, rules, norms, and routines, in a way that would become social behavior.[9]

Similarly, food security situation in Pakistan is not encouraging. A study of the years 2004 to 2016 found the food security incidence in the country at 30 to 37 percent – 29 to 47 percent in urban and 26 to 32 percent in

the rural areas.[10] A World Food Programme (WFP) study of 2009 indicated that almost half of Pakistan's population was food insecure in 2008, and that the food insecurity had worsened than in 2003.[11] According to the *National Nutrition Survey 2018*, around 40 percent of children below five years of age have stunted growth, and 17.7 percent suffered from wastage of food. Nearly one-third of children were found underweight (28.9 percent). There were 36.9 percent of food-insecure households in the country, of which 18.3 percent faced severe food insecurity.[12] The 2022 floods have severely impacted over 33 million people including the farmlands, farmers, and infrastructure in 116 of the 154 districts of Pakistan.[13] The research for this paper was primarily conducted before this calamity and does not fully incorporate its impact in its discussion. This study aims at assessing if food insecurity has increased over time in four dimensions of food availability, food accessibility, food utilization and food sustainability, and the current conditions only reinforce its findings.

Food Availability

In order to ensure food availability and minimize hunger and food insecurity, public policies are designed to take care of the supply i.e. food production and supply, and consumption i.e. access to food.[14] In the food chain, food production is the key for food availability, food security, and income generation for the off-farm and on-farm workers.[15] Food production is determined and influenced by costs at farm, input prices, and availability of resources such as land, water, and technology. The main drivers of productivity at household levels include the land area available to peasants, their household, and livestock size. The degree of market accessibility is highly influenced by the relationship of these drivers.[16] Climate change too has posed a serious threat and challenge to food production. Extreme heat has caused decrease in cereal production by 9 to 10 percent during 1964 and 2007.[17]

The impact of COVID-19 has been serious on agriculture, food supply chain, and eventually food security in various parts of the world.[18] Pakistan could, however, sustain this pressure without much harm to routine life and the agrarian country was able to benefit from its sufficient food production and food availability. The agriculture sector of Pakistan earlier adjusted itself to a reasonable degree to the growing issue of climate change. A review of adaptation practices for climate change had shown that farmers had used the adjustment in sowing time, use of draught resistant varieties, and shift to new crop as tools to adapt to the changing climatic conditions.[19] Food production and food availability are, therefore, not major problems in Pakistan but access to sufficient and quality food is surely a major concern that leaves a significant

number malnourished.[20] In Pakistan, food grain production rate is nearly the same as the population growth rate.

Food Accessibility

Access to food has a direct connection with the quality of life. Food inaccessibility causes nutrition deficiency. With the increase in education, healthcare and accommodation expenses, some families may have to compromise on their food consumption.[21] The 'Entitlement Approach' of Amartya Sen brought a big shift from food availability to food accessibility when he theorized famines to suggest that famines were not caused primarily by ineffective supply but by the ability of people to access food, which is determined by several factors including ggender, age, education, inflation, assets, employment and diseases.[22] Food insecurity in Pakistan increased during 2004-2008 and 2011-2014 while decreased during 2009-2010 and 2014-2016.[23] Food insecurity incidence was found high in Balochistan and Sindh where employment opportunities are lower than other areas of the country.[24] Food insecurity trends showed visible impact of natural calamities, conflict, and food price hike.

Food Utilization

Food utilization concerns good usage of accessed food by households or individuals and emphasizes dietary diversity including micronutrients. Food insecurity increased from 58 percent in 2005-2006 to 77.4 percent in 2013-14 but urban households are more food insecure than rural (82.2 percent and 74.9 percent respectively) in Pakistan.[25] There is significant difference in food consumption patterns of households and in dietary diversity, food variety, and calories intake during winter and summer. In winter, diversity is around 30 percent in food variety, 13 percent in dietary diversity, and 8 percent in calories intake, and even in this aspect the rural households consumed more nutritious food in winter than urban households.[26] Apart from factors like age, education, and socio-cultural constrains, there is a need to promote proper cooking training, awareness about benefits of nutritious food, efficient management, and planning to promote balanced healthy food and reduce discrimination among gender vis-à-vis food utilization.

Food Sustainability

Food sustainability relies on adequate possession of food at all times, independent of shocks, stresses, or cyclical calamities.[27] 'Sustainable food' primarily concentrates ability or potential to sustain food. Sustainable FNS are

a food system's capacity to render FNS with socially, economically and environmentally sustainable measures.[28] The stability in future food supply is a real challenge because of environmental issues, water resources depletion, population growth, and governance disparities.[29] The sustainable diet is related to governance of future food system on sustainable footing and it constitutes on four goals: nutritious diet and health, cultural acceptance, economic soundness, and environmental auspices.[30] The condition of sustainability satisfies when cost, duration, and the chain of related activities are met with demand.[31]

The nature of this research study is to quantify all four dimensions of food and nutrition security that are directly and indirectly linked to public policies. This study explores if existing public policies are working in isolation to these four dimensions of food and nutrition or there exists some integration. In view of the current literature, this study has identified certain questions to explore: such as identifying the implicit and explicit linkages between food security and nutrition security in public policies, assessing effectiveness of these policies in tackling the issue of food and nutrition security in Pakistan, and ascertaining how the four dimensions of food and nutrition security complement each other. Also, it analyzes how far the nutrition security is considered the key determinant of food security, how significant is the dietary diversity as an indicator for nutrition security, detecting the factors that are causing failure to the public policies both in formulation and implementation, and what sort of holistic package of public policies is required to address the multidimensional aspects of food insecurity in Pakistan.

The scope of this research study is to figure out and develop a comprehensive policy paradigm in light of working public policies in Pakistan. Moreover, it identifies where twists in public policies can bring fruitful results through policy formulation and implementation in Pakistan. Methodology has been devised to achieve the objectives of this research study.

Results and Discussion

The methodology and the considerations in it have been described in the Annexure and the following section delineates the research outlined in it. The discussion focuses four key dimensions of food security: food availability, food accessibility, food utilization, and food sustainability.

Deducing Outcomes to Food Availability

Food availability only covers one aspect of food security. It actually indicates the availability of the minimum dietary requirements of a household.[32] It is the mean distance that disassociates food insecure household from the food insecurity line. Severity of food insecurity concerns the distance disuniting the food unsecured from the food insecurity line, and the inequality among the food unsecured households.[33]

Overall Scenario of Food Availability Across the Samples

The whole scenario regarding all dimensions of food security in 2008 and 2018 has been presented in Table 3 with the indication of food insecurity lines. In case of food availability, at least 170 metric tons in 2008 and 1360 metric tons in 2018 were required annually at district level to take them out from food insecurity to food security. Results show that food availability dimension of food security has seen improvement over time in all three levels of incidence, depth, and severity. The incidence of food insecurity was 24 percent and 39 percent in 2008 and it decreased to 16 percent and 27 percent with the mean values of 66 percent and 75 percent cut offs or thresholds of food insecurity aversion. Similarly, depth and severity scores have also depicted the same situation in which food insecurity has come down over time. These results are consistent with the findings of other researches that there is no serious problem of food availability in Pakistan.[34]

Food Availability among Farmers and Non-Farmers

Food insecurity lines are shown in Table 4 and can be interpreted with reference to the Table 3. Food insecurity in terms of food availability has decreased both in farmers and non-farmers from 25 percent in 2008 to 19 percent and 20 percent to 10 percent in case of taking 66 percent cut-off. Moreover, food insecurity decreased 5 percent in 2008 and 9 percent in 2018 more for farmers than non-farmers. With the cut-off of 75 percent, this scenario has been similar. Overall, with the depth and severity of food insecurity at 66 percent and food insecurity aversion 75 percent, food insecurity has been decreasing more in non-farmers than farmers. This means that food security has increased more in non-farmers in term of food availability over time. These results are consistent and endorsed by the facts that risks associated to farmers' food security are due to limited income and inadequate resources.[35]

Rural-Urban Picture Regarding Food Availability

Rural and urban situation through food insecurity line in terms of food availability has been estimated in Table 5. The results clearly reflect that average food insecurity was 27 percent (rural) and 15 percent (urban) in 2008 which decreased to 19 percent in rural and 17 percent in urban in 2018 with 66 percent cut-off, respectively. Food insecurity in terms of food availability on average decreased more in rural (12 percent) than urban (2 percent). However, with the cut-off of 75 percent in rural area, food insecurity decreased by 9 percent from 2008 to 2018 while in urban it decreased 15 percent on an average. The same pattern was observed in case of depth and severity of food insecurity. These findings indicate that rural community might be facing problems in market access. Food security at local level depends upon access to food and food distribution mechanism.[36] In the Asian regions, lack of proper transport infrastructure for food and low access to market are a few key factors among others.[37] Post-production losses, illegal food products movement, inefficiency in procurement, mismanagement in distribution and pricing systems, high food inflation, and marketing are key factors affecting food security.[38]

Food Accessibility Reflection Across the Households

Income of the households was used as the proxy for food accessibility. Food insecurity line of 2008 is estimated at 3003.3 PKR and 4468.6 PKR for 2018 per month per person as the minimum requirement to take people out of food insecurity. Food insecurity lines are also estimated and interpreted for rural-urban and for farmers-non-farmers over time. The overall situation regarding food accessibility across the total samples is presented in Table 3. However, results for famers and non-famers are shown in Table 4 while rural-urban picture is depicted in Table 5. Food security in terms of food accessibility has also improved over time.

Table 3: Overall Unidimensional Food Insecurity (UDFI) Scenario in (2008 and 2018)

Unidimensional Food Insecurity (UDFI)								
F. S Dimensions	Years	FILs	Incidence of FI	Incidence of FI	Depth of FI	Depth of FI	Severity of FI	Severity of FI
		(PKR, MT, Kcal/Day)	2/3 of mean (α =0)	3/4 of mean (α =0)	2/3 of mean (α =1)	3/4 of mean (α =1)	2/3 of mean (α =2)	3/4 of mean (α =2)
Food Availability	$Z_{2(2008)}$	170 (MT)	0.24	0.39	0.05	0.08	0.01	0.02
	$Z_{2(2018)}$	1360(MT)	0.16	0.27	0.02	0.04	0.00	0.01
Food Accessibility	$Z_{3(2008)}$	3003.3 (PKR)	0.29	0.35	0.06	0.08	0.02	0.03
	$Z_{3(2018)}$	4468.6 (PKR)	0.21	0.29	0.04	0.06	0.01	0.02
Food Utilization	$Z_{4(2008)}$	4624.11(Kcal/ Day)	0.27	0.35	0.05	0.08	0.01	0.02
	$Z_{4(2018)}$	3287.9 (Kcal/Day)	0.35	0.38	0.05	0.09	0.01	0.03
Food Sustainability	$Z_{5(2008)}$	2178.3 (PKR)	0.15	0.26	0.01	0.04	0.00	0.01
	$Z_{5(2018)}$	3006.9 (PKR)	0.16	0.27	0.01	0.04	0.00	0.01

As shown in Table 3 that 8 percent food insecurity decreased from 2008 to 2018 with 66 percent cut-off and 14 percent decreased with 75 percent cut-off. It can also be observed that food security of depth and severity in term of food accessibility has improved over time. It is because household income has increased. This increase has negative relation with food insecurity.[39] Households that have reliable source of income and market access have increased food security.[40]

Table 4: Unidimensional Food Insecurity Scenario Among Farmers and Non-Farmers (2008 and 2018)

Unidimensional Food Insecurity (UDFI)								
F. S Dimensions	Years	FILs	Incidence of FI	Incidence of FI	Depth of FI	Depth of FI	Severity of FI	Severity of FI
		(PKR, MT, KK/Day)	2/3 of mean (α =0)	3/4 of mean (α =0)	(2/3 of mean (α =1)	3/4 of mean (α =1)	2/3 of mean (α=2)	3/4 of mean (α =2)
Food Availability	$Z_{2F(2008)}$	166(MT)	0.25	0.42	0.05	0.08	0.01	0.02
	$Z_{2F(2018)}$	133(MT)	0.19	0.31	0.03	0.05	0.00	0.01
	$Z_{2NF(2008)}$	177 (MT)	0.20	0.35	0.04	0.07	0.01	0.02
	$Z_{2NF(2018)}$	141(MT)	0.10	0.20	0.01	0.03	0.00	0.01
Food Accessibility	$Z_{3F(2008)}$	2838.2 (PKR)	0.27	0.34	0.05	0.08	0.01	0.03
	$Z_{3F(2018)}$	4609.7 (PKR)	0.23	0.30	0.04	0.06	0.01	0.02
	$Z_{3NF(2008)}$	3289.7 (PKR)	0.29	0.37	0.06	0.09	0.02	0.03
	$Z_{3NF(2018)}$	4223.9 (PKR)	0.18	0.26	0.03	0.05	0.01	0.01
Food Utilization	$Z_{4F(2008)}$	5027.2 (Kcal/Day)	0.24	0.33	0.04	0.07	0.01	0.02
	$Z_{4F(2018)}$	3451.2(Kcal/Day)	0.34	0.39	0.05	0.09	0.01	0.03
	$Z_{4NF(2008)}$	3924.2(Kcal/Day)	0.24	0.28	0.06	0.08	0.02	0.03
	$Z_{4NF(2018)}$	3005.1(Kcal/Day)	0.35	0.39	0.06	0.09	0.02	0.03
Food Sustainability	$Z_{5F(2008)}$	2252.6 (PKR)	0.16	0.27	0.02	0.04	0.00	0.01
	$Z_{5F(2018)}$	3117.3 (PKR)	0.16	0.24	0.02	0.04	0.00	0.01
	$Z_{5NF(2008)}$	2050.7 (PKR)	0.20	0.25	0.03	0.05	0.00	0.01
	$Z_{5NF(2018)}$	2816.8 (PKR)	0.28	0.35	0.05	0.08	0.01	0.02

Food Accessibility for Farmers and Non-Farmers

Table 4 suggests that food insecurity has increased from farmers to non-farmers with the difference of 2 percent at 66 percent cut-off while 3 percent surged with 75 percent cut-off from 2008 to 2018. However, within farmers, food insecurity decreased 4 percent and in non-farmers it decreased 6 percent from 2008 to 2018 at 66 percent threshold. In non-farmers, it decreased more with difference of 11 percent with thresholds of 66 percent and 75 percent from 2008 to 2018. This picture is also observed in case of depth and severity of food

insecurity in term of food accessibility from 2008 to 2018 in the same table. Table 5 shows that food insecurity in terms of food accessibility in rural areas decreased 6 percent against 8 percent in urban during 2008 to 2018.

Rural-Urban Depiction of Food Accessibility

While comparing rural and urban households in terms of food accessibility, 8 percent decrease in food insecurity was observed from 2008 to 2018. Food accessibility within these years in rural and urban has been decreasing while remaining stable while comparing between the two areas in the whole region. Same situation was observed in case of depth and severity. This is justifiable because urban dwellers have more livelihood opportunities than restricted opportunities in rural areas. The overwhelming majority of population (90 percent) in rural areas depends on agriculture for livelihood; and they lack the potential of dealing with the issue of food insecurity while food poverty is higher in rural areas as compared to urban areas.[41]

Food Utilization Among all Households

The minimum health status, converted into food intake, for a healthy body is considered fundamental condition for achieving food security.[42] Food utilization was assessed in terms of dietary intake by the households. The estimated food insecurity for 2008 was 4624.11(Kcal/Day) and 3287.9 (Kcal/Day) for 2018 which was the minimum requirement to make people food secure in this dimension. Similarly, the food insecurity lines are also estimated and interpreted for rural-urban and for farmers/non-farmers over the time. Table 3 shows that food insecurity in terms of food utilization or calories intake has been increasing over time. Food insecurity on average has increased 8 percent from 2008 to 2018 with 66 percent threshold while it increased 3 percent with 75 percent cut-off. However, depth of food insecurity remained same with 66 percent and 75 percent cut-offs. While severity of food insecurity has surged slightly with 1 percent with both cut-offs over time. The Households Dietary Diversity Score (HDDS) is associated with the economic ability of households to have access for variety of foods items.[43] For an active and healthy life, the human body has to effectively utilize the available nutrients of the food consumed.[44]

Farmers and Non-Farmers' Food Utilization Presentation

In Table 4, food insecurity within farmers has increased 10 percent on average from 2008 to 2018. In 2008, farmers' and non-famers' food insecurity

remained same but in 2018 it increased just 1 percent with 66 percent cut-off. Within farmers, it increased 6 percent from 2008 to 2018 on average and in non-farmers, it increased 11 percent on average from 2008 to 2018 with 75 percent cut-off. However, in case of depth and severity of food insecurity, it has been increasing, while it is stable with 75 percent cut-off over the time. The calories intake in urban poor is lower than the rural poor.[45]

Rural-Urban Food Utilization

Table 5 suggested that food insecurity has increased 5 percent in rural areas and 13 percent in urban areas on average from 2008 to 2018 at 66 percent threshold. However, when we see across these communities from rural-to-urban over time, food insecurity was lower in 2008 as compared to 2018. Food insecurity in rural and urban in 2018 has increased 10 percent on average with threshold level of 75 percent. Therefore, over time, food insecurity has increased in urban population as compared to rural in term of food utilization. This situation is also reflected in depth and severity of food insecurity that has increased across the communities and over time. The situation has been aggravated by COVID-19, particularly for densely populated urban areas.[46] Despite better public health prevention measures, urban areas were more affected.[47]

Food Sustainability Trends

'Sustainable food' primarily relates to the ability or potential to sustain food. Sustainable FNS is a food system's capacity to render FNS in socially, economically, and environmentally sustainable manner.[48] The condition of sustainability is fulfilled when cost, duration and dependent activity chains are met with demand.[49] The food insecurity lines for 2008 and 2018 regarding food sustainability have been estimated by calculating HDI considering health, education, and income expenditures (2008 and 2018). Estimated results indicate that overall food insecurity in terms of food sustainability has increased slightly from 15 percent in 2008 to 16 percent on average in 2018 with 66 percent threshold. Same is the case with 75 percent cut-off for 2008 and 2018. At least 2178.3 PKR in 2008 and 3006.9 PKR in 2018 was required to take people out from the food insecurity to food security.

Food Sustainability Among Farmers and Non-Farmers Over Time

The food insecurity lines for farmers and non-farmers for 2008 and 2018 were calculated by using HDI as a proxy. The food insecurity lines for famers for

2008 and 2018 are 2252.6 PKR and 3117.3 PKR, respectively. However, food insecurity lines for non-farmers for 2008 and 2018 are 2050.7 PKR and 2816.8 PKR accordingly. It means that at least these amounts of money are required to take the farmers and non-farmers out of food insecurity to food security in the dimension of food sustainability. The results indicate that within farming community food insecurity remained stable while in non-farming it has increased 8 percent on an average from 2008 to 2018. Moreover, food insecurity from farmers to non-farmers increased 4 percent on average from 2008 to 2018, while in the same year of 2018 there was 12 percent surge on average across these two communities at 66 percent threshold level. Food insecurity at 75 percent cut-off has also increased across communities and over time. Furthermore, depth and severity of food insecurity with 66 percent and 75 thresholds have also marginally increased over time and between farmers and non-farmers. Agriculture production and livelihood from it is considered and acknowledged an important factor for food sustainability and food availability.[50] There is tendency of unsustainability in agriculture production in the provinces of Pakistan.[51]

Table 5: Unidimensional Food Insecurity Scenario Between Rural and Urban (2008 and 2018)

Unidimensional Food Insecurity (UDFI)								
FS Dimensions	(Z_s)	FILs	Incidence of FI	Incidence of FI	Depth of FI	Depth of FI	Severity of FI	Severity of FI
	Rural and Urban	(PKR, Ton, KK/Day)	2/3 of mean (α =0)	3/4 of mean (α =0)	(2/3 of mean (α =1)	3/4 of mean (α =1)	2/3 of mean (α=2)	3/4 of mean (α =2)
Food Availability	$Z_{2R(2008)}$	167000 (T)	0.27	0.42	0.05	0.08	0.01	0.02
	$Z_{2R(2018)}$	133000 (T)	0.19	0.31	0.02	0.05	0.00	0.01
	$Z_{2U(2008)}$	177000(T)	0.15	0.32	0.03	0.06	0.01	0.01
	$Z_{2U2018)}$	143000 (T)	0.17	0.17	0.01	0.03	0.00	0.01
Food Accessibility	$Z_{3R(2008)}$	2879.9 (PKR)	0.30	0.37	0.06	0.09	0.02	0.03
	$Z_{3R2018)}$	4403.1 (PKR)	0.24	0.31	0.04	0.07	0.01	0.02
	$Z_{3U(2008)}$	3321.1 (PKR)	0.22	0.32	0.04	0.07	0.01	0.02
	$Z_{3U(2018)}$	4629.3 (PKR)	0.16	0.26	0.03	0.05	0.01	0.01

Food Utilization	$Z_{4R(2008)}$	4858.2 (Kcal/Day)	0.29	0.34	0.05	0.07	0.01	0.02
	$Z_{4R(2018)}$	3421.2 (Kcal/Day)	0.34	0.38	0.06	0.09	0.02	0.03
	$Z_{4U(2008)}$	4053.8 (Kcal/Day)	0.22	0.33	0.04	0.07	0.01	0.02
	$Z_{4U(2018)}$	2963.3 (Kcal/Day)	0.35	0.48	0.06	0.10	0.02	0.03
Food Sustainability	$Z_{5R(2008)}$	2199.9 (PKR	0.15	0.28	0.02	0.04	0.00	0.01
	$Z_{5R(2018)}$	3014.4 (PKR)	0.17	0.28	0.02	0.04	0.00	0.01
	$Z_{5U(2008)}$	2137.4	0.14	0.22	0.02	0.03	0.00	0.01
	$Z_{5U(2018)}$	2988.7	0.19	0.29	0.02	0.04	0.00	0.01

Food Sustainability-Based-Food-Insecurity Outlook in Rural and Urban Areas

In Table 5, the food insecurity lines for urban area in 2008 and 2018 are drawn at 2199.9 PKR and 3014.4 PKR, respectively, and in urban area at 2137.4 PKR and 2988.7 PKR in 2008 and 2018, respectively. The estimated results suggest that food insecurity was lower in 2008 than 2018 in urban area. 15 percent rural population and 14 percent urban population was food insecure in 2008 while in 2018, figures stood at 17 percent and 19 percent for rural and urban populations respectively. The finding that rural population in Pakistan is more food insecure than urban is not in line with some studies.[52] However, in a post- COVID-19 scenario, urban areas looked more vulnerable and affected than rural.[53]

Multidimensional Food Insecurity

Multidimensional food security is calculated by assigning different weights to each of the four dimensions of food security on the basis of data availability and calculation. The fundamental concern during the construction of composite incidences relates to developing aggregation of the information.[54] The main aspect of aggregation is assigning the weights to the components while combining them.[55] Assigning equal weight emphasizes 'neutral approach', which means avoiding any hierarchy among the dimensions. This approach has strong assumption of perfect substitutability among the dimensions. When unequal weights are concerned, perfect substitutability lacks but contains theoretical consistency while weights remain arbitrary. Therefore, arbitrary weights are assigned. The lowest weight (15 percent) was assigned to food availability dimension because data was available and calculated at national, province and district level. Food accessibility was

calculated from the income of the respondents and was assigned 20 percent weight. Food utilization has been estimated by the proxy of dietary intake of households and is assigned 20 percent weight. Food sustainability was estimated through the proxy of HDI and it was assigned 35 percent weight. The calculated results are presented in Tables 6, 7, and 8.

Food Insecurity Among Population with Equal and Unequal Weights

Table 6 shows that food insecurity remained constant over time with equal weight, while increasing 3 percent on average with 66 percent threshold with unequal weight. The incidence of food insecurity with 75 percent cut-off shows that food insecurity drops with 2 percent on average with equal weight and remains stagnant with unequal weight. The depth and severity of food insecurity also reflect that food insecurity remained constant with equal weight at 66 percent cut-off and decreased by 1 percent on average with unequal weight. However, at 75 percent threshold level of food insecurity aversion, it reversed in a sense that it decreased 1 percent on average at equal weight but remained stable with unequal weight.

Table 6: Multidimensional Food Insecurity (MDFI) Scenario Overall (2008 and 2018)

Multidimensional Food Insecurity (MDFI)								
All Dimensions of F. S	Comparison		Incidence of FI	Incidence of FI	Depth of FI	Depth of FI	Severity of FI	Severity of FI
	Weights	Year	2/3 of mean (α =0)	3/4 of mean (α =0)	2/3 of mean (α =1)	3/4 of mean (α =1)	2/3 of mean (α =2)	3/4 of mean (α =2)
$M.D.F.I.I_{O\alpha}$	Equal Weight	2008	0.24	0.34	0.04	0.07	0.01	0.02
		2018	0.24	0.32	0.04	0.06	0.01	0.02
$M.D.F.I.\ I_{O\alpha}$	Unequal Weight	2008	0.25	0.34	0.05	0.07	0.01	0.02
		2018	0.28	0.34	0.04	0.07	0.01	0.03

Food Insecurity Between Farmers and Non-Farmers with Equal and Unequal Weight

Food insecurity situation between farmers and non-farmers has been presented in Table 7. Food insecurity in non-farmers was greater than farmers with equal and unequal weights. Food insecurity increased on average by 2 percent in farmers while in non-farmers, it increased 3 percent. With unequal weights, food insecurity in farmers increased 4 percent but in non-farmers, it increased 6 percent with 66 percent threshold level. Similarly, with 75 percent cut-off,

food insecurity in non-farmers increased with unequal weights. The depth and severity of food insecurity shows the similar trend with 66 percent and 75 percent cut-offs of food insecurity aversion level.

Table 7: Multidimensional Food Insecurity (FI) Scenario Among Farmers and Non-Farmers (2008 and 2018)

Multidimensional Food Insecurity (MDFI)								
F.S Dimensions	Weights	Years	Incidence of FI	Incidence of FI	Depth of FI	Depth of FI	Severity of FI	Severity of FI
			2/3 of mean (α =0)	3/4 of mean (α =0)	(2/3 of mean (α =1)	3/4 of mean (α =1)	2/3 of mean (α=2)	3/4 of mean (α =2)
$M.D.F.I.I_F$	Equal Weight	2008	0.22	0.33	0.04	0.06	0.01	0.02
		2018	0.24	0.31	0.04	0.06	0.01	0.02
	Unequal Weight	2008	0.23	0.33	0.04	0.06	0.01	0.02
		2018	0.27	0.33	0.05	0.07	0.01	0.02
$M.D.F.I.I_{NF}$	Equal Weight	2008	0.25	0.33	0.05	0.07	0.01	0.02
		2018	0.28	0.33	0.05	0.04	0.01	0.02
	Unequal Weight	2008	0.26	0.34	0.05	0.08	0.01	0.02
		2018	0.32	0.36	0.05	0.06	0.02	0.03

Food Insecurity in Rural-Urban with Equal and Unequal Weights

Table 8 depicts food insecurity between rural-urban communities. Food insecurity with equal weight remained same while it increased with unequal weights among the rural community from 2008 to 2018. However, in urban region, food insecurity increased both with equal and unequal weights with a difference of 5 percent and 8 percent on an average respectively from 2008 to 2018. The depth and severity of food insecurity results reflected that food insecurity is stable with small increase particularly in the urban population of the studied area.

Table 8: Multidimensional Food Insecurity Scenario Between Rural and Urban in (2008 and 2018)

Multidimensional Food Insecurity (MDFI)								
F.S Dimensions	Weights	Years	Incidences of FI	Incidences of FI	Depth of FI	Depth of FI	Severity of FI	Severity of FI
			2/3 of mean (α =0)	3/4 of mean (α =0)	(2/3 of mean (α =1)	3/4 of mean (α =1)	2/3 of mean (α=2)	3/4 of mean (α =2)
$M.D.F.I.I_{Ru}$	Equal Weight	2008	0.25	0.35	0.04	0.07	0.01	0.02
		2018	0.25	0.33	0.04	0.07	0.01	0.02
	Unequal Weight	2008	0.26	0.34	0.04	0.07	0.01	0.02
		2018	0.28	0.35	0.05	0.08	0.02	0.02
$M.D.F.I.I_{Ur}$	Equal Weight	2008	0.20	0.32	0.03	0.06	0.01	0.02
		2018	0.25	0.34	0.04	0.07	0.01	0.02
	Unequal Weight	2008	0.21	0.33	0.04	0.01	0.01	0.02
		2018	0.29	0.38	0.05	0.01	0.01	0.02

Table 9: Policy Imperatives for Sustainable FNS

FNS Dimensions	**Policy Derivatives/ Recommendations**	
	Alpha Policy Scenarios	**Beta Policies**
Food Expenditure	• Food price regulation mechanism is needed to revisit in order to fulfill dietary energy requirements of the people.	• Control food inflation
Food Availability	• Food productivity is in surplus. • People are food-secure in terms of food availability.	• Rising cost of production, affecting farmers' income.
Food Accessibility	• People are food-secure in terms of food accessibility due to rise in income status. • Need to revisit government provision of health structure. • Performance is improving of government educational institutions.	• Health facilities demand clarion call to revisit health policy.

Food Utilization	• Food insecurity increasing over time and across regions. • Need knowledge and awareness about dietary diversity. • Assets-based consumption increasing rather over ensuring balance diet.	• Dietary diversity policy is needed and must be aligned with health policy.
Food Sustainability	• A small percentage of food insecurity increased in terms of food sustainability, however, similar patterns over time. • Requires inputs price regulation. • HDI indicators are at high stress and vulnerable to affect food sustainability.	• Food sustainability policy required (societal welfare rather than only food stability in terms of production and climate change).

Conclusion

The findings of this study show that food insecurity across the dimensions of food utilization and food sustainability increased from 2008 to 2018. However, the urban population is more food insecure than the rural in terms of these two dimensions of food security. It is very ironic and at the same time unusual that farmers and the rural areas are food insecure in the dimensions of food availability and food accessibility in Pakistan's fundamentally rural economy. It is also obvious from the findings that non-farmers and urban population have less dietary diversity than farmers in rural areas. The quality of optimal nutrition intake and dietary diversity positively and effectively impacts the immune system. In the era of COVID-19, when people suffered conspicuously, healthcare systems appeared inadequate to tackle the pandemic. This study showed that urban population is more food insecure than rural population particularly in the food utilization and food sustainability dimensions. People of both the regions are secure in terms of food availability and food accessibility.

Agriculture, which is considered the backbone of the economy of Pakistan, can be strengthened by land reforms and internal diversification. Reallocation of land can help to improve poverty reduction and food security. Diversification in crops and credit schemes would increase production, farmers' income and reduce food inflation.[56] The multinomial results reveal that fertilizer availability at government subsidized rate, seeds productivity performance, changing pattern of sowing and adaptation to climate change have positive and statistically significant relation to crops productivity (food availability). The performance of public educational institutions and food price regulation have positive and statistically significant impact on food accessibility while food inflation and people's knowledge about food as basic

right have negative impact. Increased spending on education, inflow of remittances, encouraging livestock package in agriculture sector, family planning, and employment opportunities are the convenient policy options to ensure food security.[57] Collaboration of government ministries, departments, task forces and commissions can bring significant change for good governance in Pakistan.

Demographic shifts and climatic change are main drivers of sudden shocks to food production. Policy interventions are adopted domestically while the affecting factors demand collaborations at regional and international level. New technology, efficient irrigation, provision of agriculture credit, and continuous application of agriculture practices are necessary to avoid future conflict.[58] Though increased use of water poses medium term and long-term threats, it has contributed to increased food availability along with increased area of cultivation and importing more cooking oils and pulses.[59] The post-shock managements in food supply chain are good for incremental progress to ensure the food availability. A paradigm shift is required in policy arena to tackle the food insecurity problems in a broader perspective by incorporating technological advancement, and generate demand in market through public-private stakeholders' involvement.[60] There is a need that the institutions and governments switch-off from economic growth and switching-on to conservation economy that will help stop environmental degradation and stimulate human activities to attain a sustainable future for all.[61]

Appendix A

	National Level ('000'T)			**Province ('000'T)**			**District ('000'T)**	
Food Groups	2008	2018	Food Groups	2008	2018	Food Groups	2008	2018
Meat	3613	5,069	Meat	317.15	676.91	Wheat	371.9	320.95
Milk	34,064	46682	Wheat	14202	18624	Rice	84.6	67.75
Wheat	20,959	25,076	Rice	2990	3162	Pomegranate	10.21	8.0
Rice	5,563	7,450	Apple	3.47	3.60	Banana	1.60	0.0
Apple	441.58	645.2	Banana	9.46	0.90	Citrus	357.30	185.15
Banana	157.32	135.05	Citrus	2219.32	2196.3	Dates	57.76	73.98
Citrus	2294.47	2262	Dates	44.36	43.24	Guava	134.59	38.19
Dates	557.52	453.37	Guava	422.32	425.28	Mango	200.26	286.25
Guava	538.89	535.11	Mango	1373.11	1301.49	Chilli	2.36	1.33
Mango	1753.69	1733.94	Pomegranate	97.73	88.30	Garlic	9.29	3.84
Cucumber	314.27	564.61	Chilli	8.10	0.10	Onion	84.12	54.23
Chilli	116.1	26.5	Carrot	164.5	84.62	Potato	1048.5	2039.1
Carrot	2365.90	2419.07	Garlic	23.37	24.65	Groundnut	2.01	1.15
Garlic	63.8	72.95	Onion	260.48	349.3	Tomato	137.5	41.65
Onion	2015.23	1,981.7	Potato	2587.5	3735.7	Mash	0.08	0.06
Potato	2539	3,853.9	Tomato	70.09	115.30	Masoor	32.3	1.03
Tomato	536.22	620.10	Squash	62012	58192	Moong	288.6	56.45
Mash	7.33	7.5	Mash	11.8	2.25	Gram	2.94	0.10
Masoor	8.6	6.7	Masoor	4.2	4.75	Fodder	339.8	125.9
Moong	120.69	118.8	Moong	137.11	130.5	Mattar	23.75	1.00
Gram	474.6	307.95	Gram	387.5	261.0			
Pomegranate	56.63	37.30						

Resources: Agriculture Marketing Information Service, Directorate of Agriculture (Agriculture and Marketing), Punjab, Pakistan; Bureau of Agriculture Statistics, Director of Agriculture Crop Reporting Service Punjab, Lahore Punjab Pakistan; Economic Wing Ministry of National Food Security s& Research (MNFS&R) Islamabad.

Annexure

Methodological Considerations

Theoretical Framework

This work attempts at developing a theoretical model for determination of food security that is constructed within the household utility model framework.[62] Some households are consumers and producers of their food at the same time. Therefore, household utility model is within the consumer consumption (demand) and production (supply) framework. Theoretical model is as follow:

$$U_i = f(D_i, L_i | y_i) \quad (1)$$

where U_i is a twice differentiable utility function that is rigorously quasi-concave, D_i is the vector of ith household demand for consumption that includes D_f food and D_{nf} non-food, L_i represents devoted leisure time and y_i explains the vector of socioeconomic and demographic variables connected to the households. It is included here that household utility is derived from combined decisions taken by households' members with respect to their preferences. The preceding definition of D_i can be segregated as:

$$D_i = (D_f, D_{nf}) \quad (2)$$

Some households are consumers and producers of the food, therefore, D_f is further considered as a vector that is home-grown food items f_{hg} and market-based consumed food items f_{mc}. Therefore, D_f is stated as follow:

$$D_f = (f_{hg}, f_{mc}) \quad (3)$$

the Becker's (1981) utility function is constructed by substituting Eq. 2 and Eq.3 into Eq.1 and this establishes utility function as:

$$U_i = f[(D_f, D_{nf}), L_i | y_i] \quad (4)$$
$$U_i = f\left[[(f_{hg}, f_{mc}),\ D_{nf}] L_i \middle| y_i\right] \quad (5)$$

the households which produce and consume at the same time are subsequently subject to some constraints of income, production and time factors. The optimization of Eq. 5 demands that the production and consumption decisions of the households are taken separately with the assumption that they all are connected to market. Therefore, firstly production decisions are made and as a result, income is allocated between consumption of commodities and leisure. It is imperative to consider that the assumption of food consumption or food security often depends upon production variables rather than vice versa.[63] Income, production and time constraints into optimization of Eq. 5 that can be taken are as follows:

Production Constraint

$$f(Q_{hg}, L, S^0, K^0) = 0 \quad (6)$$

Equation 5 specifically represents household production function for home-grown Q_{hg} food and twice differentiable by assumption (increasing outputs, decreasing inputs and rigorously convex), S^0 explains for farm size, K^0 is fixed stock of capital and L is total labor force applied in the farm.

Income Constraint

$$P_{fp}(Q_{hg} - M_{hp}) - P_{mp}f_{mc} - P_{nf}D_{nf} - w(L - l_s) + I = 0 \quad (7)$$

In Eq. 7, P_{fp} is the price for food produced, $Q_{hg} - M_{hp}$ represents market surplus of produced food, w is wage rate, l_s is total supply of family labor in the farm, P_{mp} is a per unit price of food items purchased from market, P_{nf} is per unit price of nonfood items, D_{nf} is demand of non-food items. Likewise health, education, electricity, etc, and I is adjusted in non-farm income to ensure that Eq. 7 equals zero.

Time Constraint

$$T = l_s + l \quad (8)$$
$$l_s = T - l \quad (9)$$

Where T is time endowment of households rewarded in each time that is allocated between time spent in the farm l_s and leisure l. Putting the value of $l_s$from Eq. 9 into Eq. 7 will give the following Eq.:

$$P_{fp}(Q_{hg} - M_{hp}) - P_{mp}f_{mc} - P_{nf}D_{nf} - w(L - T + l) + I = 0 \quad (10)$$

Expanding eq. 10 gives:

$$P_{fp}(Q_{hg} - M_{hp}) - P_{mp}f_{mc} - P_{nf}D_{nf} - wL + wT - wl + I = 0 \quad (11)$$

the re-arranged eq. 10 accounts explicitly for household expenditure and income that gives:

$$P_{fp}Q_{hg} + wT + I - wL = P_{hp}M_{hp} + P_{mp}f_{mc} + P_{nf}D_{nf} + wl \quad (12)$$

in eq. 12 the left-hand side (LHS) shows income of the households while RHS shows expenditure of the households with $P_{fp}Q_{hg}$ is value of the farm produces as household income, wT is time endowment, wL is labor value and I is non-farm income. Similarly, RHS demonstrates household expenditure. $P_{hp}M_{hp}$ is the value of food consumed from

household home produced, $P_{mp}f_{mc}$ is value of food consumed from market purchased, $P_{nf}D_{nf}$ is the value of the expenditure on non-food items and wl is leisure purchased. The optimization of Eq. 5 leads to expenditure and income equation with the assumption of separability that is necessary to meet first order conditions. It is also equally possible and important to optimize Eq. 12 to develop consumption and production equations separately. The households which produce food at home, demand for inputs and output produced. It is derived from maximizing by first-order condition of the LHS of Eq. 12 with respect to output produced (Q) and labor (L) as:

$$L^* = l^*\left(P_{fp}, w, S^0, K^0\right) \tag{13}$$
$$Q^* = Q_{hg}^*\left(P_{fp}, w, S^0, K^0\right) \tag{14}$$

where L^* is used optimum labor, Q^* represents optimum output. Now, there is substituting Eq. 13 and Eq. 14 into LHS of Eq. 12 that gives Full income or optimum income Y^* keeping in view the assumption of profit maximization π^* as:

$$Y^* = P_{fp}Q^* + I + wT - wL^* \tag{15}$$
$$Y^* = wT + \pi^*(P_{fp}, w, S^0, K^0) + I \tag{16}$$

however, $\pi^*\left(P_{fp}, w, S^0, K^0\right) = P_{hp}Q^* - wL)$. The demand for goods of the household D_f is derived by solving the first order condition of the Eq. 12 on RHS. However, D_f in Eq. 3 is a vector of f_{hg} and f_{mc} that depends upon their respective prices. The relationship is shown below:

$$D_f = d_f(P_{hg}, P_{mc}, P_{nf}, w, Y^*) \tag{17}$$

the demand for goods of the households also depend upon the members and their preferences. These preferences are attributed to demographic characteristics of the households in Eq. 17. Therefore, foregoing with the Eq.16, there is specified Y^* in Eq. 17 as:

$$D_f = d_f(P_{hg}, P_{mc}, P_{nf}, w, Y^*(P_{fp}, w, S^0, K^0)|y_i) \tag{18}$$

where $f = hg, mc$ while Eq. 18 explains that consumption D_f of households depends upon prices of food and non-food, household income and wages. Therefore, demand for goods of households or their consumption expenditure can measure the household food security while food security has four key dimensions: food availability (FA), food accessibility (FAc), food utilization (FU) and food sustainability (FS). Therefore, production is the measurement of food availability, income is the determinant of food accessibility, consumption or food expenditure is the determinant of food utilization, and food security based human development can be the measurement of food sustainability. This relationship can be presented as:

$$D_f \approx FS_i = (FA, FAc, FU, FS) \tag{19}$$

where *FS* is the vector of various dimensions of household food security that can be connected to food expenditure, nutrient intake, dietary diversity, production index, education index, health index, income index and role of the government institutions.[64]

Data Collection and Studied Site

Data for this study was principally collected from July 2018 to August 2018 by formulating g a questionnaire and conducting a cross-sectional field survey. The seminal samples consist of 402 households from a district's total population of (1,368,659)[65] that are representative samples with rural (285) and urban (117) households in three stratums. A pilot field survey with 10 percent samples from the targeted area was conducted before the commencement of the original field survey to get deeper understanding of the problem that is to be studied. It helped us carefully include and exclude the sub-variables into main variable construction for seeking correct information. The sample size was determined by Multistage Proportionate Stratified Random Sampling (MSRS). The MSRS is applied on homogeneous groups or similar characteristics of the population. In each stratum or group sample size is proportionate to the population size of that stratum. The formula used in sample selection is: $n = \frac{\mathrm{N}}{1+\mathrm{N}\,(e)^2}$ [66]. where n represents sample size, N indicates population size and e is the precision level. According to this formula, 71 percent samples belong to rural population) and 29 percent to urban population. The sample selection was stratified geographically and ecologically into regions, zones, and sub-zone. There were three stratums (Tehsils or zones) of a district. In ecological spectrum, sample was stratified into urban, rural, farmer and non-farmer categories. Therefore, the data was collected from 75 villages (rural) and 3 cities (urban) with geographical categorization of each stratum or zone into North, South, East, West and Central. The three cities were Bhawana, Chiniot, and Lalian in District Chiniot.

The reasons for the selection of this area for research were multidimensional. District Chiniot experienced floods in 2012 and 2014 that affected 361 villages (118,0200 population) from which 136 were affected.[67] This area faces multidimensional issues including poverty, inequality, inflation, poor quality goods, and less diversified societal consumption patterns. According to the *Pakistan National Human Development Report: Unleashing the Potential of a Young Pakistan* (2017), 47.4 percent population of this district has been facing multidimensional poverty while deprivation to overall poverty (education 45.5 percent, health 23.0 percent, living standard 31.5 percent) has been posing serious challenge.[68]

The population of this district has been engaged in agriculture, manufacturing business, and physical labor to earn their livelihoods. This study investigated the implementation, impact, and effectiveness of the government policies regarding FNS security, although there are micro and macro, societal and cultural factors that have been affecting this phenomenon. Majority of the population, approximately 71 percent, of this selected region has been residing in rural area and earning livelihood from agriculture. However, 30 percent constitute urban population. Therefore, this

study focuses on both rural-urban farm and non-farm households, those which are satisfied, and those which are unsatisfied from the public policies for fostering FNS security. One interest was to study the distinctive experience of the agriculturist households, which had owned or rented land, and non- agriculturist households, regarding government policies (Input and output related) on food availability, food accessibility, food utilization and food sustainability with the interval of 2008 and 2018. This specific interval also relates to the impact of international financial crisis on local financial conditions and the devastating floods in 2014.

The questionnaire was formulated by thoroughly reviewing the literature. In order to get mature responses, it was determined that respondents must not be below the age of 35 years. The field survey was conducted in August 2018 through recall methods for the interval of 10 years i.e. from 2008 to 2018. The geographical-ecological zones of this area are given below in Table 1.

Table1: Geographical-Ecological Zones of Studied Area

	Rural			**Urban**		
District (402)	Zone1: Bhawana	Zone2: Chiniot	Zone3: Lalian	City1: Bhawana	City2: Chiniot	City3: Lalian
	North (19)	North (19)	North (19)	North (13)	North (13)	North (13)
	South (19)	South (19)	South (19)	South (13)	South (13)	South (13)
	East (19)	East (19)	East (19)	East (13)	East (13)	East (13)
	West (19)	West (19)	West (19)	West (13)	West (13)	West (13)
	Centre (19)	Centre (19)	Centre (19)	Centre (13)	Centre (13)	Centre (13)
Rural=285 Urban=117	95	95	95	39	39	39

Indexing of the Variables

The four dimensions collectively determine the status of food security at national and household levels.[69] However, when the analysis is restricted to individual and household food security, the factors to be analyzed include income, intake of dietary energy, food allocation at intra-household, money to buy food,[70] food impoverishment,[71] gap between required and actual calories,[72] difference in 'available' per capita calories and 'required' calories for households,[73] and questionnaires for food frequencies with different recall periods.[74]

Food Expenditure **($Z_{1(2008\ \&\ 2018)}$)**

Monthly per capita food expenditure was calculated from monthly total food expenditure and total household members of a household. This variable is used as a proxy variable of food utilization (nutrition status) and food intake in Pakistan has

been determined through food composition table.[75] Food expenditure at household level is considered a better determinant of nutrition status or calories intake than income because households try to maintain smooth consumption pattern over time while income fluctuates more frequently.[76] The calories intake has been calculated through this method.[77]

Food Availability **($Z_{2(2008\ \&\ 2018)}$)**

It is calculated by arranging food groups included in the production of staple crops, vegetables, fruits, and pulses at district, provincial, and national levels in 2008 and 2018. Average productivity (at district, provincial, and national levels) is taken as a proxy whereas data is not completely available for determining the food availability for 2008 and 2018.

Food Accessibility **($Z_{3(2008\ \&2018)}$)**

Income is considered as a determinant factor in food accessibility and defines affordability of food.[78] Food access also refers to having a source of sufficient income or land to grow food.[79] It depends upon the entitlement of the individuals that depends largely on their endowments.[80] For food availability determination, per capita monthly income has been calculated from monthly income (in PKR) and members of a household.

Food Utilization **($Z_{4(2008\ \&2018)}$)**

Food utilization ascertains individuals' nutritional status by satisfying the physiological needs.[81] Dietary energy consumption (DEC) has been calculated as determinant of food utilization. The values of calories from food items in the groups have been calculated from Food Composition Table (FCT) of Pakistan.[82] The procedure adopted for food utilization determination is given below in analytical framework section.[83]

Food Sustainability **($Z_{5(2008\ \&2018)}$)**

This dimension is calculated by taking Human Development Index (HDI) as its determinant. However, HDI is static in nature. In this research, it has been transformed from static to dynamic. It is calculated by taking geometric mean of the three-dimensional incidence. The static nature of HDI is given as:

$$HDI = (I_{Health} \cdot I_{Education} \cdot I_{Income})\ 1/3 \qquad (20)$$

However, in this research study nutrition status (food expenditure in 2008 and 2018) is considered the proxy of I_{Health}, food utilization (dietary intake in years 2008 and 2018) for $I_{Education}$and food accessibility (income in 2008 and 2018) the determinant of I_{Income}.

Static and Dynamic HDI_{FSO} Calculation

Following Alkire and Sarwar,[84] monthly per capita food expenditure, monthly per capita income, and daily per capita dietary intake for years 2008 and 2018 have been measured along with 2/3 geometric mean of these variables. To calculate incidence of dynamic nature of HDI_{FSO}, the food insecurity lines of monthly per capita food expenditure 2008, monthly per capita income 2008 and daily per capita dietary intake 2008 have been applied on monthly per capita food expenditure 2018, monthly per capita income 2018, and daily per capita dietary intake 2018 to determine the $I_{S.Health}$, $I_{S.Education}$ and $I_{S.Income}$. The food insecurity lines of monthly per capita food expenditure 2018, monthly per capita Income 2018 and daily per capita dietary intake 2018 are used on monthly per capita food expenditure 2008, monthly per capita Income 2008 and daily per capita dietary intake 2008 to determine $I_{D.Health}$, $I_{D.Education}$ and $I_{D.Income}$. Now, the geometric of dynamic natures of these variables are taken. Finally, static and dynamic nature of the variables with power 1/6 would be in this form:

$$HDI_{FSO} = (I_{S.Health} \cdot I_{S.Education} \cdot I_{S.Income} \cdot I_{D.Health} \cdot I_{D.Education} \cdot I_{D.Income})\ 1/6 \quad (21)$$

whereas $I_{S.Health}$ is static incidence of health index, $I_{S.Education}$ represents static incidence of education index, $. I_{S.Income}$ indicates incidence from static income index while $I_{D.Health}$ shows dynamic incidence of health index, $I_{D.Education}$ epitomizes incidence from dynamic education index and $I_{D.Income}$ typifies incidence from dynamic income index.

Analytical Framework

Procedure for the Calculation of DEC

In this procedure, the average cost of the calories consumed while away from home are the same as calories consumed at home and develop eq. 22:

$$CPcal_{dh} = \left(\frac{\Sigma_{d=1}^{q} FEXP_d}{\Sigma_{d=1}^{q} tcal_d}\right) \quad (22)$$

Here, the caloric value in unit or cost per calorie at household level is calculated by dividing each food expenditure of households on 'q' food quantities ($\Sigma_{d=1}^{q} FEXP_d$) with the respective total kilocalories ($\Sigma_{d=1}^{q} tkcal$) of the households. Median cost or price per calorie across households are calculated in order to minimize the impact of errors of measurements in Household Expenditure Survey (HES) and to take account for the quality difference at decile, province and region.[85] For this purpose, the study considered one province, three regions, and ten deciles. Hence, the average price per calorie has been calculated (1*3*10=30) by applying the following equation:

$$CPcal_{cdh} = median\ (CPcal_h) \quad (23)$$

where, $'CPcal_{cdh}'$ is median price or cost per calorie at province, region and decile levels. This gives us a unique value of $CPcal_{cdh}$ for individual expenditure at decile level in rural and urban areas of each province. This calculated value of price per calorie is used to determine expenditure on the food quantities.

$$tkcal_{ih} = \Sigma_{\mathrm{d}=1}^{\mathrm{k}} \left(\frac{\left(\frac{FEXP_d}{CPcal_{prd}} \right)}{r} \right) \tag{24}$$

Here, $'k'$ shows food quantity when tkcal cannot be calculated from this procedure, and $'r'$ is the reference period through which food quantities are consumed or acquired as mentioned in the HES. The same method is used in raw food items along with missing quantities to average price per calorie at decile, province and region levels. After that, expenditure on each quantity is divided by its respective price of per calorie to achieve value of tkcal.

Adult Equivalent Factor

Age & sex adjustment composition is made for the households because HES just gives information about the food consumption at the household level while DEC varies across households due to difference in size and age-sex composition of the households. Therefore, adult equivalent size for each household is calculated by using the following eq. 25. The adult equivalent factor (AEF) compares energy needs of the individuals along with an adult male having moderate activity.[86] It is assumed that there is equitably distributed food among the members of the households.[87]

$$AEF_h = \Sigma_d^{hsize} AEF_d \tag{25}$$

Table 2: Adult Equivalence Scale

Age Group (Years)	**Kilocalories Per Day**	**Equivalent Factor**
Infants and young children	Average Energy per Person Daily Requirement	Adult -equivalent reference scale is 2750
6-11months	708	0.26
1-3	1022	0.37
4-6	1352	0.49
7-9	1698	0.62
Girls		
10-17	2326	0.85
Boys		
10-17	2824	1.02
Adult Men		
18-59	3091	1.12
60 and above	2496	0.91

Adult Women		
18-59	2408	0.86
60 and above	2142	0.78

In order to get the adult-equivalent reference value or scale, the mean calorie requirements for women (aged18-59) and men (aged18-59) are calculated in Table 2 (3091+2408= 5499/2=2750) accordingly in calculation of F NS board guidelines.[88] The adult-equivalent fraction assigned to each individual was determined by the ratio between the calorie requirements (according to age and gender) and the estimated adult reference value (2,750kcal). The fractions varied from 0.25 of infant and young children to 1.12 of adult men and women age ranges from 18 to 59 years.

Estimation of Daily Total Energy Acquisition (Per Adult Equivalent)

The per adult total daily equivalent DEC ($DTEAtkcal_d$) is calculated at household level by dividing the sum of calories estimated from above procedure by taking adult equivalent size of the household respectively, as mentioned below in eq. 26:

$$DTEAtkcal_d = \frac{tkcal_d}{AEF_h} = \left(\frac{(tkcal_{dh} + tkcal_{ih})}{AEF_h}\right) \quad (26)$$

Households' Food Security Status

The $DTEAtkcal_d$ of the households is now compared to their minimum dietary energy requirements (MDER) in order to determine whether a household is food insecure or food secure. The Foster, Greer and Thorbecke (FGT) approach is relevant here.

FGT Index Calculation

Basically, the FGT model for the decomposable measurement of poverty[89] has been used in literature to calculate levels of food security.[90]

$$P_\alpha = \frac{1}{\mathrm{n}} \sum_{i=1}^{q} \left(\frac{Z - Y_i}{X}\right)^\alpha$$

Households are represented by n, q denotes the number of households that are below food insecurity line, Z is food insecurity line, Y_i indicates on average *ith* households are food insecure and α represents FGT cut-offs or thresholds that show food insecurity aversion. Three cut-off levels have been put at 33 percent (1/3 of mean), 66 percent (2/3 of mean) and 75 percent (3/4 of mean).[91] However, 33 percent (1/3 of mean) is not considered in the results for being insignificant. A larger P_α shows position of the most food insecure household. The implications are: if $P_\alpha = 0$, then FGT index P_α measures incidence of food insecurity.[92] This represents the percentage of the households that are impoverished. While $P_\alpha = 1$ measures the depth of food insecurity

among the members of the households. This indicates the proportion of gap that an average food insecure household need to fill to get above the food insecurity line. Moreover, $P_\alpha = 2$ measures severity of food insecurity among the members of a household that tells the comparison across regions and years. The FGT Index is bounded between 0 and 1. The closer the FGT Index value to one, greater the food insecurity. However, this index has been widely used to determine levels of poverty.[93]

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