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Spatial Evaluation of Multidimensional Energy Poverty in Punjab, Pakistan

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ABSTRACT

The intense objective of the present study is to explore the multidimensional energy poverty in Punjab with regions and administrative divisions by utilizing couples of the latest Household Integrated Economic Survey (HIES) datasets, i.e., 2015-16 and 2018-19. The study uses the well-organized, globally accepted indexing method of Alkire and Foster (2011) to explore the outcomes of energy poverty in a multidimensional context. Outcomes of multidimensional energy poverty evaluate that in the study area, energy poverty is purely a rural phenomenon across each dual cut-off from K=2 to 4 because rural areas residences are most victimized of a precise social threat compared to urban regions. Over time comparison reveals the declining trend of energy poverty at the provincial level as well as across a maximum number of divisions and their representative areas. Finally, comparative measurements deliberately explore that across divisions, D.G. Khan is harshly victim of multidimensional energy poverty in both base and terminal years compared to all other divisions. Further, calculated measures of the multifaceted energy poverty approach demonstrate that energy poverty with a varying cut-off from 2 to 4 gets declined, which means the maximum population of the study area is mainly deprived of basic energy services. Therefore, as per policy concern, especially in multiple aspects energy poverty context, it is need of the time, on one side, to improve the financial status of the households while on the other side, it is also necessary to provide basic energy services like electricity and gas at the doorstep of the families mainly resides in rural areas. With the availability of primary energy services and high financial status, they also utilized modern energy appliances for home use, communication and entertainment, ultimately leading to a decline in energy poverty in the area under study.

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INTRODUCTION

In a modern era of advanced technology and industrial development, still emerging economies of the universe are facing severe social challenges like corruption, tax aversion, money laundering, income disparity and underprivileged pro-poor growth, etc. among all these, the prevalent problem is poverty which has shed devastating influence on these economies (Cheema & Sial, 2012, Wang et al., 2021 & Shah et al., 2022). Traditionally, confab on poverty was roughly grounded on a single dimensional continuum or deficiency of financial aspect, i.e., income (less than $1.25, $1.50 & $2/day) which destitute common person or household of purchasing an inevitably prerequisite basket of goods for the gratification of money-oriented as well as social needs to endure contented life (World Bank, 2011; Saboor et al., 2015). Nevertheless, after the 1970s, especially the pivotal work of Sen (1976) on the key notion of the 'capability approach,' the debate on poverty was not limited to a single dimensional aspect, i.e., deficiency of financial element. Instead, it was broadly pondered as a multidimensional notion with denial of intensely desired crucial ingredients like education, health and elementary housing amenities that are imperative for a comfortable life (Khan et al., 2015 & Mustafa et al., 2016). In a quite recent era, particularly a decade back, due to severe energy crises and deprivation in key energy ingredients that are important for a human being at an individual as well as household level, various sociologist, economist and development policy developer has given a new direction to multidimensional poverty idea that is extensively regarded as 'multidimensional energy poverty' (Mendoza et al., 2019; Rao et al., 2022). No doubt, the empirical methodology of both the classical multidimensional poverty measure and the new multiple-aspect energy poverty measure is the same. But due to its keen importance and devastating influence, it has gained acute interest in the least developed economies literature in a pretty slighter period of time (Lin and Okyere, 2020 & Ashagidigbi et al., 2020).

Like the basic poverty measure, the primary debate on energy poverty was also widely based on the single-dimensional notion and basic expenditure on energy services was used as a key indicator to explore (Mbewe, 2018). However, the debate on energy poverty was transmitted from single dimensional concept to a multidimensional attitude after the adaptation of sustainable development goals (SDGs) as well as millennium development goals

(MDGs) (Assembly, 2015). Defined advancement in technique authenticates the wider evidence about comfort in one side and on another, it sets an ample trail for understanding energy poverty (Alkire and Santos, 2010). Uplift in disposable income or energy expenditure is alone pondered a delicate standard to guarantee the lessening in the magnitude of energy poverty in different energy-related social and economic aspects in the society. Hence, to measure energy poverty generally, the capability approach provides an advanced version through various indicators like lighting, communication, cooking, home appliances & entertainment apart from income (Nussbaumer et al., 2013).

Raising energy crises is a burning challenge of the current century that has harshly affected almost all the economies of the universe so dangerously. As per eminence of the social menace of energy poverty, various scholars defined it in different ways in different spans of time like, Boardman (1991) defined it as the nonexistence of access to contemporary energy amenities like gas and electricity. Pereira *et al*. (2011) defined energy poverty as a scarcity of disposable income that deprived residents of easy access to contemporary or outdated frequently used energy sources. Imran & Jawad (2015) explained energy poverty as an uplift in the prices of energy amenities or a noteworthy discrepancy in the supply of energy resources. Foster *et al*. (2000) definite energy crises in the views of affordability and affirm that residents are energy deprived if their expenditure is insufficient to enjoy basic energy services as per the society where they live.

Reducing poverty in agrarian economies has become a crucial concern for economists and development policymakers in this modernized age of capital formulation and industrial progress. Conventionally, the debate on poverty was widely made as a uni-dimensional idea and only income/ consumption expenditure is used as key variables to measure it. But later on, especially at the end of 20th century Sen (1976) "capability idea" gave a new direction to the debate on poverty known as "multidimensional poverty". Further, he also highlighted that a single dimension of income/ consumption expenditure is not quite a strong measure to predict the true situation of the economy. However, in a comprehensive way and under a logical, globally accepted indexing method, Alkire and Foster (2011) first discussed poverty as a multiple attributes phenomenon. They demonstrated how much residents of developing countries are deprived of basic facilities of life like education, health and housing services. Based on precise methodology, a wide array of literature has been found that reconnoiter poverty is a multidimensional notion. Nevertheless, the existing study has no special concern with basic multidimensional poverty issues because such study has made a special focus on the emerging problem of energy poverty while discussion of multidimensional poverty before energy poverty is considered as important because multidimensional energy poverty is an important stem or extension of multidimensional poverty. In light of the above discussion, it has been observed that no distinct effort has been found yet that widely highlighted the multidimensional energy poverty in the province of Punjab, its representative divisions and regions. Therefore, the research gap of the extent of multidimensional energy poverty at the provincial, regional and divisional levels in Punjab, Pakistan, is yet to be addressed. So, the inimitability of the current study is that it made an extraordinary effort to bridge the above-mentioned gap and also tries to answer the following key questions:

Research Questions

1. What type of dimensions structure is required to measure the extent of multidimensional energy poverty at the divisional and regional level in the Province of Punjab?
2. What is the magnitude of multidimensional energy poverty at the divisional level in the Province of Punjab?

REVIEW OF LITERATURE

In the current era, due to the increasing world population and limited energy resources, the energy sector all over the globe is facing three non-ignorable challenges. The initial one is the climate-induced challenge which strongly debates the access of common human being to clean energy services. The second one has a key concern with the security of energy supply towards the universal energy market. The third and relatively important but ignored one is energy poverty. The initial two challenges have been part of the abundant stream of literature. However, as per prominence, especially for developing economies, there is limited research on the third one (González-Eguino, 2015).

Pelz et al. (2018) critically reviewed the phenomena of multidimensional energy poverty and concluded that Multidimensional Energy Poverty (MDEP) has two basic issues; it is too difficult to have a uniform practical use at the worldwide level. These procedures are so inflexible that their national-level appropriateness is low. Thus, serious hard work is necessary to abridge and combine these measures. The worldwide tracking agendas should have consistency as well as contextualization features. One common set should be espoused for global assessments. One subset should be agreed upon that can capture country-specific dynamics. Similarly, Broto *et al.* (2017) criticized the energy poverty literature as having high skewness towards rural areas. They think that the scope of energy poverty studies should give equal importance to urban areas because they can also have energy-poor households. The research agenda should be revised in the context of urban energy needs.

Nussbaumer *et al.* (2013) estimated Multidimensional Energy Poverty (MDEP) for several developing countries by utilizing basic multidimensional poverty methodology and each country's survey datasets, which are taken from their

statistical departments. Estimated outcomes highlighted that Pakistan's Multidimensional Energy Poverty (MDEP) is 45%, with headcount estimates 0.69% and deprivation intensity of 0.66. India's Multidimensional Energy Poverty (MDEP) is 56% with headcount and intensity estimates 0.75. Bangladesh had a Multidimensional Energy Poverty (MDEP) score of 71%. Its headcount and intensity are 0.92 and 0.77, respectively. Finally, Maldives had the quite smallest Multidimensional Energy Poverty (MDEP) score compared to all Asia region countries. The Multidimensional Energy Poverty score is only 3%, with Headcount is 0.06 and intensity of 0.46, respectively.

On the basis of two most important dimensions, namely, availability and affordability, Crentsil *et al.* (2019) explored the multidimensional energy poverty level between 2008 and 2014 in a quite deprived country of Ghana. The calculation was done under the basic multidimensional poverty method using repeated cross-sectional data. The estimated outcomes revealed the decreasing trend of multidimensional energy poverty in the study area. However, despite this declining trend of Multidimensional Energy Poverty (MDEP), incidence and intensity are still higher due to structural and policy shocks. These higher measures revealed that despite the declining trend of Multidimensional Energy Poverty (MDEP), higher dimension deprivation is still quite a severe issue for residents of Ghana.

Mendoza *et al.* (2019) studied the problem of Multidimensional Energy Poverty (MDEP) in 81 provinces of the Philippines by utilizing cross-sectional survey data from multiple years from 2011 to 2016 and the basic indexing procedure of Alkire and Foster (2011). Empirical outcomes designated that Multidimensional Energy Poverty (MDEP) had presented a declining trend in all 81 provinces of the Philippines from 2011 to 2016. However, measurement of deprivation level revealed that across all seven attributes, a household is declared energy poor if its deprivation score is greater than or equal to 50%. Empirical calculations evaluated that Autonomous Region in Muslim Mindanao (ARMM) and Region IX are the poorest provinces.

Falak et al. (2014) estimated the dilemma of Multidimensional Energy Poverty (MDEP) in all four provinces of Pakistan by employing the indexing method of Alkire and Foster (2011) and cross-sectional data of PSLM (Pakistan Social and Living Standard measurement). Results demonstrated that in all four provinces namely, Punjab, Sindh, Khyber Pakhtoon Khaw (KPK) and Baluchistan, 47%, 51%, 69% and 66% of the households are multidimensional energy poor. However, dimensional decomposition revealed that indoor pollution is the principal contributor to overall household energy poverty in all the described key four provinces. Ranking-wise measures revealed that the deprivation of indoor pollution lies between 49% and 63%. Cooking fuel deprivation is the second, between 35% and 59%. Finally, the least deprivation lies in terms of appliances. A comparative measure of deprivation and poverty revealed that Baluchistan province residents are facing the highest degree of deprivation and energy poverty, while contrarily, residents of the province of Punjab are facing the smallest degree of deprivation as well as poverty.

Sambodo and Novandra (2019) estimated the dilemma of energy poverty in Indonesia by using a basic headcount ratio measure and two dimensions; households are energy poor if they spend more than 10% on energy. Households are also poor if monthly electricity consumption is below 32.4 kilowatt hours (kWH). Individual calculations of each dimension under different cut- off suggested that energy poverty headcount is around 53% under expenditure criteria. According to minimum electricity consumption criteria, 22% of households are energy poor. The study also found that malnutrition was reduced in villages due to improved access to electricity and modern cooking fuel. It was recommended that efficient use of energy by the poor could reduce energy poverty.

Pachauri *et al.* (2004) described the dilemma of energy poverty under the novel idea of two-dimensional measurement of energy poverty and energy distribution in the least developed economy of India. Precise two-dimensional procedure combined the elements of access to different energy types and quantity of energy consumed. The estimated measurement of the study area revealed a decline in energy poverty. Further, empirical measures also elaborated that the new approach is quite a better complement to the conservative monetary approach and had successful applicability in other developing countries.

Sadath and Acharya (2017) studied the emerging dilemma of multidimensional energy poverty under Amartya Sen's capability idea using India Human Development Survey data for 2012. Analytical calculations of multidimensional energy poverty (MDEP) in India revealed widespread energy poverty in the study area. Energy poverty has socioeconomic dimensions such as higher energy poverty in households with high-income poverty and higher energy poverty in the backward castes like Dalits and marginal tribes like Adivasis. Further, a precise study also endorsed the fact that women are mainly responsible for procuring HH energy services, in particular, the collection of fuelwood. They suffer from health hazards associated with the use of biomass.

Uz Zaman et al. (2023) spatially explored the dilemma of multidimensional energy poverty among farming and non-farming communities of agro-ecological zones of Pakistan by using cross-sectional data from the last decade, 2010/11 to 2019/20 and well-reputed basic indexing methodology of Alkire and Foster (2011). The calculation of the study significantly highlighted that energy poverty, in a multidimensional aspect, is purely a farming phenomenon. Moreover, the time-variant trend evaluated that multidimensional energy poverty had declined over time in the study area.

Salman et al. (2022) calculated dilemma of multidimensional energy poverty in 146 countries of different continents by utilizing data from 17 years from 2002 to 2018. Three key dimensions, affordability, cleanability and availability under 13 indicators are used to explore outcomes. Calculated outcomes substantially revealed that the energy poverty dilemma harshly victimizes developing countries compared to developed ones. However, their situation regarding the issue of energy poverty was continuously improved over time. Meaning that a decline in energy poverty has been observed. Comparative calculations of regions evaluated that Central Asia, South Asia, and Africa are severely victimized regions from energy poverty.

Mirza and Szirmai (2010) highlighted the dilemma of energy poverty in rural Punjab using a composite index and special energy poverty survey data conducted in 2009. To a wider extent, an assessment of the study substantially concluded that 23.1% of rural households experienced a high degree of energy inconvenience. 96.6% of households suffered from severe energy shortfall. A combined estimate of the inconvenience and shortfall measure revealed that the extent of energy poverty in rural Punjab was 91.70%, respectively.

METHODOLOGY

To analytically explore the dilemma of energy poverty in multiple aspects of context, especially at the provincial, regional, and divisional level in Punjab's latest rounds, i.e., 2015-16 and 2018-19, cross-sectional survey data of HIES (Household Integrated Economic Survey) has been taken under contemplation. For the empirical calculation of multidimensional energy poverty at the provincial, regional and divisional levels in the province of Punjab, five crucial attributes are selected by following various prior studies like Uz Zaman et al. (2023) Pelz *et al*. (2018); Goldemberg *et al*. (1985); Bhatia and Angelou (2014) and Modi *et al*. (2006). Detail description of each selected attribute with sub-attributes is as follows;

Figure 1: Diagrammatic View of Attributes Selected for Current Study

A periodic survey has been designed by a globally recognized organization of Pakistan Bureau of Statistics (PBS) to collect Household Integrated Economic Survey. After the collection, this Household Integrated Economic Survey data set has been arranged into dissimilar primary and Secondary Sampling Units (PSUs) & (SSUs). The primary sampling units of all the collected data sets widely contain various enumeration blocks of advanced regions and mouzas, and villages of the backward region of the study area. However, secondary sampling units have been obtained from primary sampling units which involve 16 households from each mouzas, and village and 12 households from each enumeration block. An authentic statistical method of stratified random sampling has been taken into consideration for the development of the design of selected Primary Sampling Units and Secondary Sampling Units. In the current study, two latest data sets, 2015-16 and 2018-19 of the Household Integrated Economic Survey (HIES), have been considered to numerically materialize the outcomes in Punjab, Pakistan. The Primary Sampling Units (Secondary Sampling Units) of the initial year data set, i.e., 2015-16 for the province Punjab with urban and rural region, is 697, 482, and 215 (10508, 7181, and 3327). While these estimates for the terminal year dataset, i.e., 2018-19, are 850, 350, and 500 (11781, 3945 and 7836).

Multidimensional Energy Poverty Index

Basically, poverty is studied in a one-dimensional framework. Consumption expenditure in developing countries is widely utilized as a key aspect to estimate it. Still, in a new era, the measurement of poverty is transformed from a one-dimensional idea to a multidimensional phenomenon, and a series of aspects of health, education, and housing services are used to enumerate it (Alkire and Santos, 2010). Now lately, the debate concerning poverty has further transmitted to a new idea regarded as multiple aspects of energy poverty due to severe boost in energy crises, especially in developing countries. Nussbaumer *et al*. (2012) is the pioneer who studied the energy poverty dilemma in multiple aspect concept by employing the analytical approach of Alkire and Foster (2011). The only dissimilarities they created between both simple multidimensional poverty measure and multiple aspects energy poverty measure is the use of a different set of dimensions, as mentioned above, basic multidimensional poverty measure used three dimensions (education, health and housing services) to present analytical outcomes; however, a precise measure of multidimensional poverty take into consideration five key attributes (cooking, lighting, housing services, entertainment and communication) to reconnoiter analytical results. However, to explore poverty in the scenario of multidimensional energy poverty following indexing approach has been applied.

Adjusted Headcount Index

For poverty estimation in a multidimensional spectrum in the general case or in the context of multidimensional energy poverty, a modified indexing methodology adjusted headcount ratio has been used. The precise modified indexing method extends basic single-dimensional poverty measures at the advanced level. In an indexing methodology, two-step estimations have been extensively involved; initially, the headcount ratio has been estimated due to several dimensions more than one, and the dual cut-off procedure has been adopted to calculate the number of deprived within and across the dimensions. The calculated measure of adjusted headcount ratio explores the percentage of deprived in all the dimensions taken under deliberation. It is widely denoted by 'H'. Secondly, the average deprivation gap is calculated, denoted by 'A'. Such a measure describes the sum of the average derivation of households/individuals in each dimension. Multiplication of both the calculated measures demonstrates the outcomes of the adjusted headcount index ratio. The general formula of the given measure is as follows:

$$M_0 = HA$$

Here H=q/n, the basic headcount ratio is measured in multiple aspects of context. 'q' is the number of deprived households in different dimensions, and 'n' is the total number of households. However, the average deprivation gap, 'A=∑i (c*/d)/q', where c* is the summation of deprived households across describe various aspects, 'd' is the number of dimensions, and 'q' is the total number of deprived households in different dimensions.

RESULTS AND DISCUSSIONS

In light of a described set of dimensions in the prior section, a household is considered deprived in any defined dimension if the dimension score is not more than the suggested deprivation threshold. In an initial dimension, the cooking: a household is affirmed deprived if he either has no access to advanced cooking service or faces indoor pollution issues. Correspondingly, in the second dimension, the lighting: a household is considered deprived if it does not have easy access to basic electricity service. Whereas in the next third, fourth and fifth dimensions, a household is considered deprived if it has no access to any of the two out of three facilities deliberate as sub-dimensions for the communication, entertainment, and home appliances. However, to make the conversation easier, within the dimension, the basic cut-offs for all the five key dimensions are 1,1,2,2 & 1. Lastly, the collective cut-off across the described attribute is '*k≥3'*. It simply means that a household is multidimensionally poor in a given era if it has a deprivation score greater than or equal to 3.

In light of the above discussion, the results of Table 1 present the multidimensional energy poverty at the divisional and regional levels in Punjab for the year 2015-16. Estimated results reveal that at dual cut-off K=2, in overall Punjab, 51.80% of residences are multidimensional energy deprived with an average deprivation gap of 0.567 and multidimensional energy poverty of 29.40%, respectively. Similarly, with increasing dual cut-off from 2 to K=3 and 4, the level of energy deprivation and energy poverty also changes. Results demonstrate that at K=3 in the overall province of Punjab, 31.20% of residences are multidimensional energy deprived with an average deprivation gap of 0.676 and multidimensional energy poverty estimates of 21.10%. Finally, with dual cut-off K=4, empirical results of Punjab illustrate that 10.60% of residences are multidimensional energy deprived with an average deprivation gap of 0.830 and multidimensional energy poverty calculated at 8.80%, respectively. All these estimates with changing dual cut-offs widely reveal that energy poverty in a multidimensional context has declined with increasing dual cut-offs from 2 to 4, meaning that most of the residences of the study area are severely deprived of basic energy services.

Like overall estimates, measurement of urban regions at provincial level demonstrates that at K=2, 16.50% of households are deprived in various dimensions with an average deprivation gap of 0.497 and multidimensional energy poverty estimates of 8.20%, respectively. Consistent with the above, increasing the cut-off from 2 to 4 decreases energy poverty. Estimated measurement at dual cut-off K=3 demonstrates that in urban Punjab, 6.50% of

households are deprived in different dimensions with average deprivation gap estimates of 0.662, and multidimensional energy poverty calculates 4.30%. Finally, with dual cut-off K=4, empirical results of the province of Punjab illustrate that 1.50% of residences are multidimensional energy deprived with an average deprivation gap of 0.813, and multidimensional energy poverty calculates 1.30%, respectively.

On the bases of overall Punjab and urban region results, an estimate of the rural region at the provincial level also reveals a similar pattern with smaller dual cut-off energy poverty measures are high and with higher cut-off energy poverty measures are low, which also authenticates above views that most of the residences of the study area are deprived in basic energy services. However, empirical measures display that at dual cut-off K=2, 60.30% of households are multidimensional deprived with an average deprivation gap of 0.572 and multidimensional energy poverty at 34.50%. Similarly, with varying cut-offs from 2 to K=3, multidimensional energy deprivation has declined to 37.10% with an average deprivation gap of 0.680 and multidimensional energy poverty to 25.20%. Lastly, at dual cut-off K=4, 12.80% of households are multiple aspects deprived, with an average deprivation gap of 0.836 and multidimensional energy poverty of 10.70%, respectively. By summing up the discussion, it has been noted that like a single dimensional measure of energy poverty here also in multiple attributes context, energy poverty is a rural phenomenon, and at every step of dual cut-off rural area households are severely affected by the social menace of energy poverty as compared to urban counterpart. Overall, at the divisional level trend of energy poverty has remained similar across regional contexts.

Likewise, above discussion, divisions are also described in a similar way. However, comparative analysis of division deliberately highlighted that D.G. Khan at divisional and regional levels is harshly victim of energy poverty in multiple aspects framework across each cut-off while contrarily Federal Area of Islamabad is least affected by the menace of energy poverty at an overall level as well as across the regions at every cut-off measure from K=2 to 4. Empirics of harshly victim measure explore that in D.G. Khan, from lower to the higher cut-off level of deprivation is 73.20%, 51.60%, and 20.20% with average deprivation gap 0.605, 0.692, and 0.836 and multidimensional poverty measure 44.30%, 35.70%, and 16.90%. Further, in urban (rural) regions, level of deprivation across divergent cut-offs is 25.90%, 10.70% and 2.20% (79.30%, 56.90% and 22.60%) with average deprivation gap 0.502, 0.648 and 0.818 (0.610, 0.692 and 0.832) and multidimensional energy poverty 13.00%, 6.90% and 1.80% (48.40%, 39.40% and 18.80%) respectively.

Table 1: Multidimensional Energy Poverty in Punjab with Divisions and Regions 2015-16

Regions	K=2			K=3			K=4		
	H_o	A_o	M_o	H_o	A_o	M_o	H_o	A_o	M_o
Rawalpindi	24.30	0.526	12.80	11.60	0.663	7.70	3.00	0.833	2.50
Urban	5.30	0.452	2.40	1.50	0.600	0.90	0.30	0.667	0.20
Rural	28.70	0.526	15.10	13.90	0.662	9.20	3.70	0.837	3.10
Sargodha	56.20	0.557	31.30	31.10	0.682	21.20	11.30	0.823	9.30
Urban	21.30	0.497	10.60	8.10	0.667	5.40	2.40	0.792	1.90
Rural	63.70	0.560	35.70	36.00	0.683	24.60	13.20	0.825	10.90
Lahore	34.70	0.518	18.00	15.10	0.676	10.20	4.90	0.816	4.00
Urban	11.00	0.481	5.30	3.80	0.656	2.50	0.90	0.777	0.70
Rural	45.60	0.521	23.80	20.30	0.675	13.70	6.70	0.821	5.50
Gujranwala	29.30	0.502	14.70	12.20	0.639	7.80	2.30	0.826	1.90
Urban	8.40	0.500	4.20	3.50	0.657	2.30	0.70	0.857	0.60
Rural	35.00	0.500	17.50	14.60	0.643	9.40	2.80	0.821	2.30
Multan	60.70	0.572	34.70	39.10	0.667	26.10	11.40	0.824	9.40
Urban	18.50	0.486	9.00	6.20	0.661	4.10	1.40	0.857	1.20
Rural	71.90	0.579	41.60	47.80	0.667	31.90	14.00	0.828	11.60
Faisalabad	54.70	0.564	30.90	32.60	0.678	22.10	10.90	0.825	9.00
Urban	16.30	0.503	8.20	6.70	0.656	4.40	1.60	0.813	1.30
Rural	65.60	0.570	37.40	40.00	0.678	27.10	13.60	0.824	11.20
D. G. Khan	73.20	0.605	44.30	51.60	0.692	35.70	20.20	0.836	16.90
Urban	25.90	0.502	13.00	10.70	0.645	6.90	2.20	0.818	1.80
Rural	79.30	0.610	48.40	56.90	0.692	39.40	22.60	0.832	18.80
Sahiwal	35.70	0.529	18.90	17.40	0.667	11.60	5.30	0.811	4.30
Urban	11.20	0.500	5.60	3.90	0.668	2.60	1.60	0.750	1.20
Rural	39.50	0.530	20.90	19.40	0.665	12.90	5.90	0.813	4.80
Bahawalpur	66.50	0.586	39.00	43.30	0.688	29.80	16.10	0.839	13.50
Urban	29.20	0.517	15.10	13.60	0.654	8.90	3.30	0.818	2.70
Rural	73.70	0.592	43.70	49.00	0.690	33.80	18.60	0.833	15.50
Islamabad	7.20	0.458	3.30	1.80	0.611	1.10	0.40	0.750	0.30
Urban	3.40	0.470	1.60	1.00	0.600	0.60	0.00	0.000	0.00
Rural	11.20	0.455	5.10	2.50	0.680	1.70	0.70	0.857	0.60
Punjab	51.80	0.567	29.40	31.20	0.676	21.10	10.60	0.830	8.80
Urban	16.50	0.497	8.20	6.50	0.662	4.30	1.60	0.813	1.30
Rural	60.30	0.572	34.50	37.10	0.679	25.20	12.80	0.836	10.70

Contrary to D.G. Khan, it has been widely noted that residents of the Federal area of Islamabad at each step, like across regions and in the context of dual cut-off, are least affected by the social threat of multidimensional energy poverty.

Numerical measures evaluate that at dual cut-off 2, 3, and 4 in Federal Area of Islamabad, 7.20%, 1.80%, and 0.40% residences are multiple attributes energy deprived with average deprivation gap 0.458, 0.611 and 0.75 and multidimensional energy poverty 3.30%, 1.10% and 0.30% respectively. Further, in urban (rural) regions, the level of deprivation across divergent cut-offs is 3.40% and 1.00% (11.20%, 2.50%, and 0.70%) with average deprivation gap of 0.470 and 0.600 (0.455, 0.680 and 0.857) and multidimensional energy poverty 1.60% and 0.60% (5.10%, 1.70% and 0.60%) respectively.

Results of Table 2 reconnoiter the multidimensional energy poverty at the divisional and regional level in Punjab for the terminal year, i.e., 2018-19. Estimated results reveal that at dual cut-off K=2, in overall Punjab, 30.50% of households are multidimensional energy deprived with an average deprivation gap of 0.531 and multidimensional energy poverty of 16.20%, respectively. Similarly, with increasing dual cut-off from 2 to K=3 and 4, the level of energy deprivation, as well as energy poverty also changes. Results demonstrate that at K=3 in overall Punjab, 15.50% of households are multidimensional energy deprived with an average deprivation gap of 0.665 and multidimensional energy poverty estimates of 10.30%. Finally, with dual cut-off K=4, empirical results of Punjab illustrate that 4.40% of households are multidimensional energy deprived with an average deprivation gap of 0.818 and multidimensional energy poverty calculates 3.60%, respectively. All these estimates with changing dual cut-offs widely reveal that energy poverty in a multidimensional context has declined with increasing dual cut-offs from 2 to 4, meaning that most of the households in the study area are severely deprived of basic energy services.

Like overall estimates, measurement of urban regions at the provincial level demonstrates that at K=2, 10.00% of households are deprived in various dimensions with an average deprivation gap of 0.480 and multidimensional energy poverty estimates of 4.80%, respectively. Consistent with the above, increasing the cut-off from 2 to 4 decreases energy poverty. Estimated measurement at dual cut-off K=3 demonstrates that in urban Punjab, 3.30% of households are deprived in different dimensions with average deprivation gap estimates of 0.636 and multidimensional energy poverty calculates 2.10%. Finally, with dual cut-off K=4, empirical results of Punjab illustrate that 0.70% of residences are multidimensional energy deprived with an average deprivation gap of 0.857 and multidimensional energy poverty calculates 0.60%, respectively.

Table 2: Multidimensional Energy Poverty in Punjab with Divisions and Regions 2018-19

Regions	K=2			K=3			K=4		
	H_o	A_o	M_o	H_o	A_o	M_o	H_o	A_o	M_o
Rawalpindi	10.50	0.486	5.10	3.60	0.638	2.30	0.80	0.875	0.70
Urban	6.10	0.459	2.80	1.60	0.625	1.00	0.30	0.900	0.27
Rural	12.60	0.492	6.20	4.60	0.652	3.00	1.10	0.818	0.90
Sargodha	37.20	0.508	18.90	15.90	0.654	10.40	4.30	0.791	3.40
Urban	14.10	0.475	6.70	4.40	0.636	2.80	0.80	0.875	0.70
Rural	43.10	0.512	22.10	18.90	0.656	12.40	5.10	0.823	4.20
Lahore	13.90	0.475	6.60	4.60	0.630	2.90	0.80	0.875	0.70
Urban	6.20	0.468	2.90	1.60	0.688	1.10	0.40	0.750	0.30
Rural	25.20	0.484	12.20	8.90	0.640	5.70	1.50	0.800	1.20
Gujranwala	12.10	0.462	5.60	3.10	0.645	2.00	0.50	0.800	0.40
Urban	5.30	0.452	2.40	1.10	0.364	0.40	0.20	0.500	0.10
Rural	14.90	0.463	6.90	4.00	0.625	2.50	0.60	0.833	0.50
Multan	44.40	0.543	24.10	25.10	0.653	16.40	6.40	0.813	5.20
Urban	13.60	0.500	6.80	5.30	0.660	3.50	0.15	0.800	0.12
Rural	56.20	0.548	30.80	32.70	0.654	21.40	8.20	0.817	6.70
Faisalabad	30.30	0.528	16.00	15.00	0.660	9.90	4.20	0.810	3.40
Urban	8.20	0.463	3.80	2.30	0.609	1.40	0.30	0.667	0.20
Rural	40.80	0.534	21.80	21.00	0.662	13.90	6.10	0.820	5.00
D. G. Khan	70.00	0.577	40.40	45.00	0.676	30.40	16.10	0.814	13.10
Urban	36.10	0.499	18.00	14.20	0.655	9.30	3.60	0.777	2.80
Rural	76.50	0.584	44.70	51.00	0.677	34.50	18.50	0.811	15.00
Sahiwal	24.30	0.493	12.00	9.30	0.645	6.00	1.90	0.842	1.60
Urban	5.60	0.446	2.50	1.10	0.636	0.70	0.20	0.850	0.17
Rural	27.90	0.495	13.80	10.80	0.648	7.00	2.20	0.818	1.80
Bahawalpur	56.60	0.558	31.60	34.20	0.660	22.60	9.70	0.814	7.90
Urban	22.80	0.509	11.60	9.70	0.659	6.40	2.60	0.808	2.10
Rural	65.90	0.563	37.10	41.00	0.661	27.10	11.60	0.819	9.50
Islamabad	8.20	0.439	3.60	1.20	0.667	0.80	0.10	0.800	0.08
Urban	7.50	0.440	3.30	1.50	0.600	0.90	0.20	0.500	0.10
Rural	8.90	0.427	3.80	1.00	0.600	0.60	0.10	0.800	0.08
Punjab	30.50	0.531	16.20	15.50	0.665	10.30	4.40	0.818	3.60
Urban	10.00	0.480	4.80	3.30	0.636	2.10	0.70	0.857	0.60
Rural	39.80	0.537	21.40	21.10	0.663	14.00	6.00	0.817	4.90

On the bases of overall Punjab and urban region results, an estimate of the rural region at the provincial level also reveals a similar pattern with smaller dual cut-off energy poverty measures are high and with higher cut-off energy poverty measures are low, which also authenticate the above views that most of the residences of the study area are deprived in basic energy services. However, empirical measures display that at dual cut-off K=2, 39.80% of

households are multidimensional deprived with an average deprivation gap of 0.537 and multidimensional energy poverty of 21.40%. Similarly, with varying cut-offs from 2 to K=3, multidimensional energy deprivation has declined to 21.10% with an average deprivation gap of 0.663 and multidimensional energy poverty to 14.00%. Finally, with dual cut-off K=4, 6.00% of households are multidimensionally deprived, with an average deprivation gap of 0.817 and multidimensional energy poverty of 4.90%, respectively. By summing up the discussion, it has been noted that like a single dimensional measure of energy poverty, here also in multiple attributes context, energy poverty is a rural phenomenon, and at every step of dual cut-off rural area households are severely affected by the social menace of energy poverty as compared to urban counterpart. Overall, at the divisional level trend of energy poverty has remained similar across regional contexts.

Likewise, above discussion, divisions are also described in a similar way. However, a comparative analysis of division deliberately highlighted that like the base year 2015-16 here also in the terminal year 2018-19, D.G. Khan at the divisional and regional levels harshly victim of energy poverty in multiple aspects of the framework across each cut-off while contrarily Federal Area of Islamabad is least affected with the menace of energy poverty at an overall level as well as across the regions at every cut-off measure from K=2 to 4. Empirics of harshly victim measure explore that in D.G. Khan, from lower to the higher cut-off level of deprivation is 70.00%, 45.00%, and 16.10% with average deprivation gap 0.577, 0.676 and 0.814 and multidimensional poverty measure 40.40%, 30.40%, and 13.10%. Further, in urban (rural) regions, the level of deprivation across divergent cut-offs is 36.10%, 14.20%, and 3.60% (76.50%, 51.00%, and 18.50%) with average deprivation gap of 0.499, 0.0.655 and 0.777 (0.584, 0.677 and 0.811) and multidimensional energy poverty 18.00%, 9.30% and 2.80% (44.70%, 34.50% and 15.00%) respectively.

Contrary to D.G. Khan, it has been widely noted that residents of the Federal area of Islamabad at each step, like across regions and in the context of dual cut-off, are least affected by the social threat of multidimensional energy poverty. Numerical measures evaluate that at dual cut-off 2, 3, and 4 in Federal Area of Islamabad, 8.20%, 1.20%, and 0.10% residences are multiple attributes energy deprived with average deprivation gap 0.439, 0.667 and 0.800 and multidimensional energy poverty 3.60%, 0.80% and 0.08% respectively. Further, in urban (rural) regions, the level of deprivation across divergent cut-offs is 7.50%, 1.50% and 0.20% (8.90%, 1.00% and 0.10%) with average deprivation gap 0.440, 0.600 and 0.500 (0.427, 0.600 and 0.800) and multidimensional energy poverty 3.30%, 0.90% and 0.10% (3.80%, 0.60% and 0.08%) respectively.

In the end, it has been observed that multidimensional energy poverty has also lessened in Punjab and regions and a maximum number of divisions, like single-dimensional energy poverty. The energy issues related to the common population decline with industrial development and technological advancement. However, over time income of the common man also increases, which boosts his consumption expenditure which means the living standard of the common man also improves which also compels him to utilize modern energy services and gadgets. Precise utilization of modern energy services and products also alters the common individual's lifestyle, ultimately declining the dilemma of energy poverty at the household level in the study area.

In light of the numerical outcomes of Tables 1 and 2, figure 2 has been drawn that explores the relative change in multidimensional energy poverty in the province of Punjab and its administrative divisions with urban and rural regions at dual cut-off K=2 from 2015-16 to 2018-19. Based on the above detailed of outcomes, it has been noted that over time in a maximum number of divisions, energy poverty in multiple aspects milieu presents a declining trend. However, multidimensional energy poverty has increased in Rawalpindi and D.G. Khan division's urban regions and in the Federal area of Islamabad's overall urban region from 2015-16 to 2018-19. Comparative outcomes at the divisional level demonstrate that Lahore (D.G. Khan) division at the maximum (minimum) level reduces energy poverty over time. Similarly, Sahiwal (Multan) division at the maximum (minimum) level in urban regions reduces energy poverty over time in a one-dimensional framework. Ultimately, measuring rural areas in a comparative context highlights that Gujranwala (D.G. Khan) division reduces energy poverty over time in a multidimensional framework.

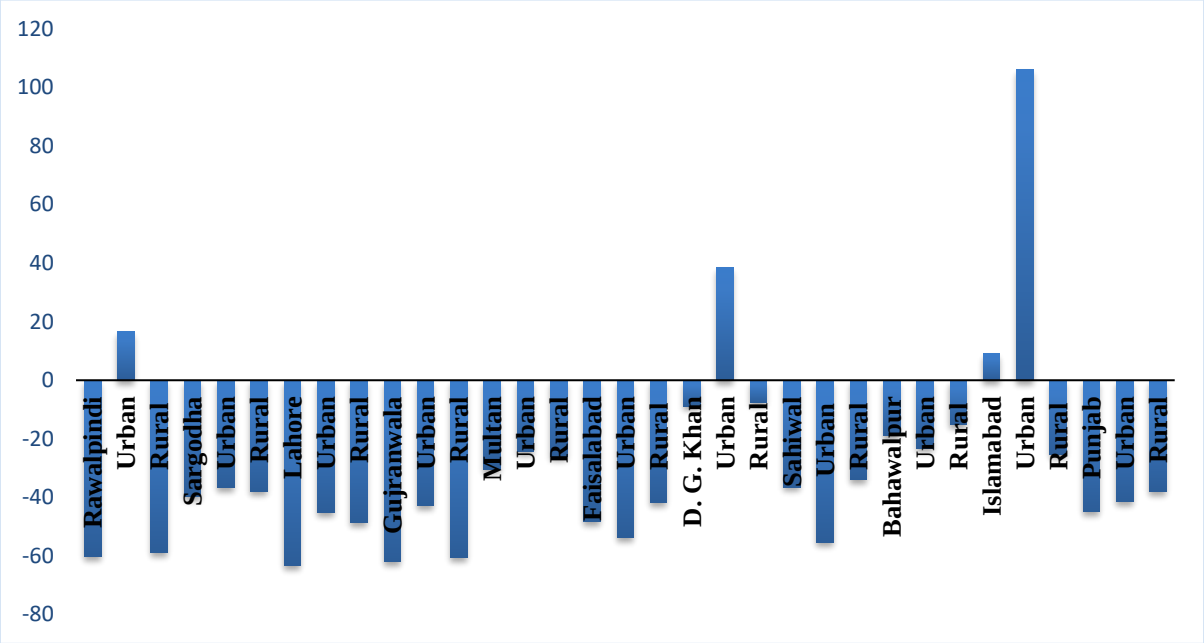

Figure 2: Relative Change in Multidimensional Energy Poverty in Punjab at 'K=2'

CONCLUSIONS

A systematic energy poverty study in multidimensional aspects has been conducted by employing two latest rounds of Household Integrated Economic Survey cross-sectional data, i.e., 2015-16 and 2018-19, to explore outcomes. The index of Alkire and Foster (2011) has been used at provincial, regional, and divisional levels in Punjab to examine the extent of multidimensional energy poverty in both base and terminal years. Outcomes of multidimensional energy poverty also conclude that in a study period, multidimensional energy poverty is purely a rural phenomenon for Punjab and its divisions. However, here it has also been noted that households of the Federal Area of Islamabad in base and terminal years are least affected by energy poverty. On the contrary, the households of D.G. Khan are harsh victims of the current issue. The reason behind this is that households residing in the Federal Area of Islamabad have higher income and easy access to basic energy sources, which leads to smaller deprivation in basic energy facilities, while on the contrary, households of D.G. Khan are harshly victims of multidimensional energy poverty because the households of particular division are mostly daily wage labor and also most of them have no access to electricity and gas facility, due to such factor (lower income and poor access to basic energy facility) they have poor access to basic equipment like gas and electricity instrument that leads to increase energy deprivation and cause severe energy poverty in precise division. However, over the time scenario evaluates that from 2015-16 to 2018-19, energy poverty at the provincial level as well as across maximum divisions in a multidimensional perspective has declined because, in a study period in Punjab, provincial as well as federal governments have taken some serious step like financially support the rural area residences, minimize energy crises, provide maximum rural households energy access at their doorstep and also given subsidy on basic energy appliances.

POLICY RECOMMENDATIONS

Based on analytical outcomes calculated earlier, by present, the following recommendations are proposed to be implemented for reducing the current problem from the area under study.

First of all, the government should focus on reducing energy crises like gas and electricity load shedding, leading to increased expenditure on various energy-useable equipment and causing a significant decline in the multidimensional perspective of energy poverty. By taking such steps, energy expenditure increases that lead to reduced energy poverty because buying various equipment leads to a decline deprivation in housing services and entertainment dimensions that ultimately leads to a decline in multidimensional energy poverty in Punjab

Secondly, rural areas are serious victims of energy poverty due to the non-availability of gas and electricity facilities, especially in southern Punjab. Govt. should focus on the rural areas of southern Punjab and provide them with basic facilities of electricity and gas so that deprivation in these dimensions is reduced, ultimately causing a reduction in energy poverty in the study area.

Most households in Punjab's rural areas are ignorant of modern energy sources, and these areas lack access to communication facilities. In these areas, the government should focus on twofold; first, the government should launch various awareness programs regarding the benefits of the use of modern energy sources; secondly, the government

should also provide communication facilities to this area at subsidized rates like easy availability of telephone and mobile phone connections at lower possible rates. All these remedies are quite helpful gadgets to decline the energy poverty dilemma in the area under discussion.

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