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# Feminization of poverty: an analysis of multidimensional poverty among rural women in China

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Few studies from an individual perspective have analyzed the multidimensional poverty of rural women in China. Therefore, based on the CFPS data from 2010 to 2020 and the Alkire-Foster approach, this study built a six-dimensional system to portray the status of multidimensional poverty among rural women. The overall comparisons found that rural women were more likely to be multidimensional poor than other subgroups. And the results of rural women showed significant demographic and spatio-temporal differences. That is, older rural women were more deprived than younger rural women. Rural women with spouses or confidence were less deprived than those without spouses or confidence, respectively. From the spatial perspective, the censored headcount ratios of rural women in descending order were Western Region, Central Region and Eastern Region. From the temporal perspective, the risk of rural women's multidimensional poverty decreased significantly from 2010 to 2020. The importance of non-material indicators was gradually becoming prominent, including education, health and subjective wellbeing. The conclusions can contribute to the development of policies, even if some limitations need to be further improved.

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## Introduction

According to Sustainable Development Goals Report 2023<sup>1</sup>, “if current trends continue, 575 million people will still be living in extreme poverty by 2030”. And gender equality remains a serious concern. “It will take an estimated 140 years for women to be represented equally in positions of power and leadership in the workplace.” As a result, women are more likely to fall into poverty than men. The female-headed households in developing countries are significantly worse wellbeing than that of male-headed households (Bikorimana and Sun 2020; Biswal et al. 2020; Milazzo and Van de Walle 2017; Tekgüç and Akbulut 2022). Due to the traditional social division of labor, women become the main responsible for housework and family care. Insufficient rest time and low productivity at work can cause time poverty and even mental health problems among women (Arora and Rada 2017). And compared with women in urban areas, women in rural areas are too deficient in social capital to withstand the risks of life, such as inequality of educational resources (Radiowala and Molwane 2021), inequality of employment opportunities (Buribayev and Khamzina 2019), shortage of financial capital (Han et al. 2019; Yu et al. 2020), poor living conditions (Wei et al. 2021), imperfect infrastructure and social welfare (Akbar et al. 2022; Wu and Qi 2017), etc. Feminization of poverty and female impoverishment have gradually become an indisputable fact (Bradshaw et al. 2019). Therefore, how to effectively identify and address rural female poverty has been a key focus of global poverty reduction.

China, the largest developing country, also faces the plight of female impoverishment. Official data showed that the poverty incidence of women was 9.8% in poverty-stricken counties, which was 0.4 percentage points higher than that of men<sup>2</sup>. The government has given the priority to reducing the quantity of poor women in anti-poverty programs. By the end of 2020, 98.99 million rural poor population had been lifted out of poverty, about half of whom were rural women<sup>3</sup>. China has eradicated absolute income poverty and achieved the poverty alleviation target of the UN’s 2030 Agenda for Sustainable Development 10 years ahead of schedule. However, poverty itself is a complex and multidimensional phenomenon, where income poverty is just one of forms (Sen, 1985). Multidimensional poverty (MP) is a persistent challenge that people need to overcome. Global MPI Country Briefing 2023 in China<sup>4</sup> reported that the MPI (multidimensional poverty index) is higher in rural areas than in urban areas. And the incidence of women’s MP is significantly higher than among men in China (Wu and Qi 2017; Yu et al. 2020). Therefore, rural women could be at a double disadvantage in terms of gender and geography. Targeted alleviation of rural women’s MP is the “key battlefields” against poor population growth. China’s experience in reducing rural women’s MP will also provide a powerful reference for other countries.

However, the observations of rural women were insufficient, although scholars applied MPI to some groups in China (Alkire and Shen 2017; Chen et al. 2019; Wang et al. 2021; Yang et al. 2021; Yu et al. 2020; Zhang et al. 2021; Zhu et al. 2022). And existing studies have mostly focused on households rather than individuals (Adepoju and Akinluyi, 2017; Bikorimana and Sun 2020; Han et al. 2019; Roy et al. 2019; Yu et al. 2020; Zhu et al. 2022). As Vijaya et al. (2014) argued, household-level measures are gender-neutral. Because they ignore differences in resource allocation within households that are gender-specific. Even in wealthy households, women may not have equal resources with men. To the best of our knowledge, some studies have focused on static data at the expense of dynamic data (Biswal et al. 2020; Chen et al. 2019; Kayo and Takashi 2016; Kilburn et al. 2020). This will undoubtedly create limitations in understanding the transmission of poverty status and providing targeted anti-

poverty interventions. Furthermore, Oxford Poverty and Human Development Initiative (OPHI)<sup>5</sup> indicated that “a national MPI is a country-specific poverty measure tailored to the unique situation of each country. Such measures generally take the dimensions of health, education and living standards as a starting point, and supplement with different dimensions measured by locally appropriate indicators.” Therefore, it is necessary to adjust the measurement dimensions of rural women’s MP in the Chinese context to provide more reliable data.

To this end, based on the microdata of China Family Panel Studies (CFPS) from 2010 to 2020 and literatures, this research tries to develop the multidimensional poverty measurement index for rural women in China. It aims to capture the static and dynamic status of rural women’s MP in China through the Alkire-Foster (A-F) approach (Alkire and Foster 2011). In terms of results, valuable suggestions can be put forward to improve the life quality of rural women. The following questions can be addressed in this text. (1) What is the status quo of rural women’s MP? (2) What are the spatial and temporal characteristics of rural women’s MP? (3) How can reduce the probability of rural women’s MP in new era? The remaining parts proceeded as follows. The literature review is introduced in Section 2. Methods and data are presented in Section 3. Section 4 shows the main results with robustness. Section 5 concludes the detail discussions. Conclusion including implications and limitations is in the final.

## Literature review

**Poverty and multidimensional poverty.** The original studies are grounded in the adequacy of material economic conditions, i.e., income-poverty line. For instance, Rowntree (1902) argued that poverty was income insufficient to meet the minimum requirements for maintaining purely physical ability. This income-based poverty assessment of individuals or households has dominated for a long time (Alkire and Foster 2011; Liu et al. 2017). However, people increasingly realize that poverty is a multidimensional and complex phenomenon. The income approach is not suitable for every situation. Some non-monetary attributes cannot be purchased in the market, including life expectancy, liberty, public goods, happiness, etc. Even if it were possible to assign a price tag on each basic need, and then add up the minimum thresholds to arrive at a monetary poverty line, it would not guarantee individuals with incomes at or even above the poverty line to actually spend their money on minimal basic needs packages (Thorbecke 2013). It is not accurate enough to draw conclusions from an economic perspective alone, as the causes of poverty also change over time (Liu and Xu 2016).

Amartya Sen put forward the capability approach to provide a powerful guide for rethinking poverty (Sen 1985; 1993; 1999a; 1999b). Based on the capability theory, functioning (i.e., achievement) and capability (i.e., opportunity and freedom) are two important interrelated concepts. Except for income, the deprivation of capabilities and opportunities also can result in poverty (Sen 1985; 1999a). Income poverty is just a survival poverty, while rights deprivation is another poverty that focuses on development. Subsequently, the World Development Report stated that poverty is a multidimensional phenomenon, including malnutrition and poor health, lack of opportunity, security and empowerment (World Bank 2001). Since then, MP has gradually been accepted in the global. It includes more attributes that may cause inequality or social exclusion, such as health, education, employment, housing, subjective wellbeing, social services, etc., to offset drawbacks of income approach (Nawab et al. 2023; Shen and Li 2022). Although it is more inconvenient to operate than the unidimensional income approach, multidimensional measurement approaches have shown

advantages in applications, including the dashboard approach, the composite indices approach, Venn diagrams, the dominance approach, statistical approaches and fuzzy sets (Nawab et al. 2023; Nasri and Belhadj 2017).

Particularly, the A-F method is a powerful measurement tool of MP (Alkire and Foster 2011; Shen and Li 2022). First, it has a rigorous statistical foundation that is based on axioms of poverty and welfare analysis. This can provide a robust and reliable results (Alkire et al. 2015). Second, it is flexible to adjust dimensions, indicators and weights according to the specific context, such as different populations, geographic areas or policy goals (Alkire and Santos 2014). Third, the A-F method can identify individuals and households who are experiencing poverty. It not only can derive MPI, but can also derive the breadth, depth and intensity of poverty. It is customized to incorporate stakeholder perspectives, ensuring that poverty is measured in a way that reflects the needs of those most affected (Nasri and Belhadj 2017). Last but not least, it provides a friendly and intuitive way for understanding and communication. The data can be accessible to a wider audience including citizens and policymakers. Due to rigor, flexibility, sensitivity, transparency and incorporating stakeholder perspectives, the A-F approach is widely used and well-regarded by policymakers, researchers and advocates around the world (Alkire and Fang 2019; Borga and D'ambrosio 2021; Koomson et al. 2020; Nawab et al. 2023; Sadath and Acharya 2017; Shen and Li 2022). It has captured the poverty in more than 100 developing countries, reflecting the poverty level of individuals or households on different dimensions (Alkire and Santos 2014). This is why the A-F approach is also adopted in this study.

**Rural women's multidimensional poverty and identification factors.** In the Sen's theory, unequal ability (opportunity and freedom) is also the core of gender inequality (Sen 1995). Although women pay a lot for daily housework, it is often ignored when calculating their contributions to the household due to direct monetary benefits not being produced (Sen 1999a). In some developing countries, deep-rooted ideas, such as patriarchal and raising sons for retirement, not only cause an imbalance in the birth ratio of boys and girls (Jayachandran 2015), but also deprive women's opportunities and rights. Even in some developed countries, women have less access to higher education than men, but are more exposed to punishment or violence (Kleven et al. 2019). For a long time, discrimination against women's rights has plagued social development.

The phenomenon of female impoverishment is prominent in low-income countries. For example, poor females lived more difficult than poor males in Nicaragua where gender inequality<sup>6</sup> exceeded 10% (Espinoza-Delgado and Klasen 2018). This trend also can be found in some high-income countries like South Korea (Hwang and Nam 2020), Japan (Kayo and Takashi 2016) and Germany (Suppa 2016). Due to differences of resources and customs in urban and rural areas, rural women are more impoverished than rural men (Biswal et al. 2020). For example, Bikorimana and Sun (2020) reported that female-headed households were more multidimensional poor than male-headed households in Rwanda. The headcount ratio of rural MP was 6 times higher than that of urban MP in other Africa countries (Megbowon 2018). Showed that the feminization of MP was significant in rural Odisha. When other conditions keep constant, the MPI increased to 0.648 if a person was female. And rural women were overrepresented in severe deprivation, including schooling, employment, social participation and so on. There was also a significant gender inequality in poverty in Turkey, ranging from 0.3 to 0.35 in all regions, and females were more disadvantaged than males (Tekgüç and Akbulut 2022).

Although some conclusions are similar in the prior literature, there are still some differences in the specific values of rural women's MP. As recommended by the OPHI, country-specific methodological considerations need to be used to capture national data. It has an advantage in obtaining individual data to support poverty governance. Accordingly, scholars employed individualized indicators to measure the female MPI in different times and places. For example, drawing from four dimensions including income, health, schooling and social protection, Kayo and Takashi (2016) found that female impoverishment was significant in China, Japan and Korea. Covarrubias (2023) used five dimensions to measure the gender difference of MP in Mexico, including education, housing, health, time privation and access to basic services in the dwelling. Kilburn et al. (2020) built a system with six dimensions to measure young women's MP in South Africa, i.e., education, food or health, protection, social relationship, psychological wellbeing and economic agency. It can be seen that dimensions are gradually enriched over time, ranging from 3 dimensions to 6 dimensions. And non-material factors such as subjective wellbeing have been included in the measurement (Decanq et al. 2019).

Based on the above, this study adjusted the measure dimensions to identify rural women's MP in China. On the one hand, the capability approach argued that life quality is triggered by far more than economic status. And the deprivation of abilities and opportunities is the root of poverty (Sen 1985; 1999a). Human needs should be effectively addressed to prevent poverty, including but not limited to income, health, education, welfare and wellbeing (Alkire, 2005). On the other hand, rural women are still at a relative disadvantage in terms of income, education, and welfare protection (Covarrubias 2023; Han et al. 2019; Wu and Qi 2017; Yu et al. 2020). The Outline for Women's Development in China (2021–2030)<sup>7</sup> stressed that the government should increase efforts to safeguard the livelihood of women in rural areas, especially in less developed areas. And it should create an enabling environment where women truly feel satisfied, happy and secure. This outline also noted that women's equal rights to education, health, employment, social security and politics must be protected. It can be seen that material revenue, social welfares and subjective wellbeing are valuable for the development of rural women in China. Therefore, we added income, social welfare and subjective wellbeing into the general measurement including health, education and living standards. This follows both the rule of national specificity supported by OPHI and the policy outlines for women's development in China. The results can more accurately capture rural women's MP in China and provide data support for the poverty reduction of rural women.

## Data and method

**Data source.** China Family Panel Studies (CFPS) was employed in this research. CFPS is a biennial longitudinal survey launched in 2010 by the Institute of Social Science Survey (ISSS) of Peking University, China. CFPS is designed to collect the longitudinal data of communities, families, and individuals in contemporary China. The database is divided into the household dataset, community dataset, adult dataset (16 years old and above) and children dataset (less than 16 years old). Based on the economic and non-economic wellbeing of the Chinese population, the survey is informative and covers topics such as economic activity, educational outcomes, family dynamics and relationships, immigration and health. In the 2010 baseline survey, the sample is drawn with implicit stratification through a multi-stage probability. Each subsample in the CFPS goes through three stages: county (or county equivalent), then village (or village equivalent), and then household in mainland China (excluding Hong Kong,

Macau and Taiwan). Interviews will be conducted utilizing the Computer Assisted Personal Interviewing (CAPI) technique provided by the Survey Research Center (SRC) at the University of Michigan. The CAPI and its associated survey-management system enable researchers to design a fairly complex interview schedule for members of the household and reduce measurement errors while allowing the management team to closely monitor the quality of field interviews. The CFPS in 2010 successfully interviewed nearly 15000 households and nearly 30000 individuals within those households. The response rate is approximately 79%. Respondents are tracked through an annual follow-up survey. So far, CFPS has published the data in 2010, 2012, 2014, 2016, 2018 and 2020, respectively, to provide scholars with solid data support (Wang et al. 2022; Wu and Qi 2017; Yang et al. 2021; Zhang et al. 2021).

This study also used CFPS dataset for analysis. Firstly, the samples were selected in each wave based on the research variables. Given the data availability and the research content, the household database was merged with the adult database to obtain complete individual information. And the missing data were removed on a case-by-case basis. Default rates were 13.27% in 2010, 20% in 2012, 25.24% in 2014, 87.93% in 2016, 21.73% in 2018 and 20.86% in 2020, respectively. However, the missing rate of BMI in 2016 (over 50%) was so high that samples in 2016 was ultimately removed from this samples (see Appendix Tables A1 and A2 for details). A total of 133557 samples were obtained in 5 waves, where samples of rural women were 33381 with an age range from 16 to 97 ( $M = 44.84$ ,  $SD = 16.32$ ). And there were 7583 in 2010, 7364 in 2012, 6939 in 2014, 6628 in 2018 and 4867 in 2020, respectively (see Appendix Tables A3 and A4 for details). Secondly, the pooled samples were extracted based on location areas (i.e., rural or urban) and gender (i.e., female or male) for subgroup comparisons. In terms of the official information<sup>8</sup>, they were divided into three economic regions for spatial comparisons, i.e., Eastern Region, Central Region and Western Region. Thirdly, based on personal ID and survey time, they were set into panel data for capturing the dynamic and static features of rural women's MP. Total sample of rural females who participated in all 5 surveys was 8950 with an age range from 16 to 87 ( $M = 46.64$ ,  $SD = 12.92$ ), of which 21.75% was in 2010 ( $M = 41.68$ ,  $SD = 12.39$ ), 21.04% in 2012 ( $M = 43.86$ ,  $SD = 12.35$ ), 20.06% in 2014 ( $M = 46.07$ ,  $SD = 12.34$ ), 18.74% in 2018 ( $M = 50.4$ ,  $SD = 12.21$ ), and 18.41% in 2020 ( $M = 52.46$ ,  $SD = 12.15$ ) (see Appendix Table A5 for other details).

**Multidimensional poverty measurement.** According to the above discussion (Alkire et al. 2015; Alkire and Shen 2017; Chen et al. 2019; Sen 1985; Wang et al. 2022; Wu and Qi 2017; Yang et al. 2021; Zhang et al. 2021), this research used 6 dimensions for measures, including income, health, education, social welfare, living standards and subjective wellbeing, with a total of 12 indicators. They were converted into binary variables ("1 = the deprived" and "0 = the non-deprived") by cutoff values. The details are as follows.

Given that some rural women were still in school or at home, the household net income per capita was used to measure the income dimension. It was measured based on the annual standard to better match the social conditions. The official poverty lines are 2300 CNY in 2010, 2625 CNY in 2012, 2800 CNY in 2014, 2995 CNY in 2018 and 4000 CNY in 2020<sup>9</sup>. If the household net income per capita is below the poverty line in the corresponding year, individuals are deprived. The assigned value is 1, otherwise it is 0.

It is worth noting that China has implemented nine-year compulsory education. And according to other domestic scholars

(Wang et al. 2022; Zhang et al. 2021), the critical value of schooling is set to 9. Persons with less than 9 years of schooling are deprived. The assigned value is 1, otherwise it is 0.

BMI, chronic diseases and self-rated health were selected for the measurement of health dimension. According to the World Health Organization (WHO), BMI is measured as weight divided by the square of height (i.e.,  $\text{kg/m}^2$ ). In line with most studies (Alkire and Fang 2019; Alkire and Shen 2017; Batana 2013; Wu and Qi 2017; Zhang et al. 2021), people with less than 18.5 BMI are undernourished. The assigned value is 1, otherwise it is 0. Similarly, persons with chronic diseases during six months and poor self-rated health are assigned a value of 1 respectively, otherwise they are assigned 0.

For the social welfare dimension, medical insurance and pension insurance were regarded as indicators. People without either form of medical insurance are deprived. The assigned value is 1, otherwise it is 0. The same applies to pension insurance.

Living standards were measured by the housing asset, drinking water, and cooking fuel. If the ownership of houses does not belong to one's own (family), it is considered to be deprived of housing asset. Likewise, people without access to clean energy or clean water are considered to be deprived. The assigned values are 1, respectively, otherwise they are 0.

According to authoritative scholars (Diener 2009; Diener et al. 2018; Kahneman and Krueger 2006), subjective wellbeing is an evaluation of people's psychological perceptions. It is closely related to people's psychological health and life quality. It is usually measured by life satisfaction, happiness and depression (Kahneman and Krueger 2006). In this way, this study regarded life satisfaction and depression as indicators of subjective wellbeing. To ensure that the depression scales were as consistent as possible, the CES-D 6 items in 2010 CFPS were used as the baseline, including emotional frustration, emotional tension, fidgeting, sense of hope, sense of difficulty, and sense of meaning in life. The recoded options were "1 = hardly ever (less than a day)", "2 = some of the time (1–2 days)", "3 = often (3–4 days)", and "4 = most of the time (5–7 days)". If a total score is greater than 10, it is considered to be depressed. The assigned value is 1, otherwise it is 0. The details can be seen in Table 1.

**The A-F method.** The A-F dual-cutoff approach is the development of Foster-Greer-Thorbecke (FGT) for poverty measurement (Foster et al. 1984). The first step is to identify whether the individual or household is deprived in each indicator. The second step is to identify whether the individual or household is multi-dimensionally deprived in all dimensions. The identification process of MP is as follows.

Specifically, the total number of assumed samples is  $N$ , and each sample has  $D$  indicators to assess the deprived levels. Then the matrix of  $N \times D$  can be formed, we can let

$$y_{ij} \in \begin{pmatrix} y_{11} & \cdots & y_{1D} \\ \vdots & \ddots & \vdots \\ y_{N1} & \cdots & y_{ND} \end{pmatrix}, \text{ denoting the value of individual } i$$

( $i = 1, 2, \dots, N$ ) on dimension  $j$  ( $j = 1, 2, \dots, D$ ).

Firstly, we need to identify the deprivation indicator, i.e., to clarify whether an individual is deprived at a particular indicator. Set the threshold value of each indicator as  $z_j$ , if  $y_{ij} < z_j$ , it indicates that individual  $i$  is deprived in dimension  $j$ , with a value of 1, otherwise with a value of 0. The new deprivation matrix is satisfied, i.e., Eq. (1).

$$g_{ij}^0 = \begin{cases} 1, & \text{if } y_{ij} < z_j \\ 0, & \text{if } y_{ij} \geq z_j \end{cases} \quad (1)$$



**Table 1 Multidimensional poverty indicators in this study.**

Dimensions	Indicators	Type	Deprived if	Weight
Economic	Per capita net income	Binary	The per capita net family income is lower than the national poverty line standard.	1/6
Education	Years of schooling	Binary	An individual is less than 9 years of compulsory schooling.	1/6
Health	Self-rated health	Binary	Self-assessed health status is poor and below.	1/18
	Chronic diseases	Binary	An individual is medically diagnosed with chronic disease during six months.	1/18
Living standards	Nutrition	Binary	BMI is lower than 18.5.	1/18
	Housing asset	Binary	Ownership of housing does not belong to himself/herself or to his/her family.	1/18
	Drinking water	Binary	Cooking with no access to any clean drinking water (e.g., tap water, mineral water, pure water, filtered water).	1/18
	Cooking fuel	Binary	Cooking with no access to any clean fuels for cooking (e.g., liquefied petroleum gas, natural gas, electricity).	1/18
Social welfare	Medical Insurance	Binary	An individual does not have any form of medical insurance.	1/12
	Pension insurance	Binary	An individual does not have any form of pension insurance.	1/12
Subject wellbeing	Life satisfaction	Binary	Life satisfaction is low and below.	1/12
	Depression	Binary	Self-rated depression score is greater than 10.	1/12

Secondly, the total deprivation score of individual *i* on all dimensions is calculated by the weights of each indicator (*w<sub>j</sub>*), i.e., Eq. (2).

$$c_i = \sum_{j=1}^D w_j g_{ij}^0 \tag{2}$$

There are two methods of weight identification, including equal weight and non-equal weight. In line with prior works (Alkire et al. 2015; Wang et al. 2022; Wu and Qi 2017; Yang et al. 2021; Zhang et al. 2021), this study used the dimensional equal weight approach for assignment. Given the correlation analysis of all indicators, the correlation coefficients are below 0.3 and the values of variance inflation factor (VIF) are less than 4 (see Appendix Table A6). It indicates that there is no strong correlation and co-linearity between the indicators with equal weights.

Thirdly, by setting the deprivation cut-off *k*, we determine whether individuals belong to MP. If *c<sub>i</sub>* ≥ *k*, individual *i* is MP, otherwise individual *i* is not MP. It can be expressed as Eq. (3).

$$c_i(k) = \begin{cases} c_i, & \text{if } c_i \geq k \\ 0, & \text{if } c_i < k \end{cases} \tag{3}$$

Finally, the deprivation matrix *g<sup>0</sup>* can be transformed into a censorship deletion matrix, i.e., *g<sup>0</sup>(k)* = [*g<sub>ij</sub><sup>0</sup>(k)*] and *g<sub>ij</sub><sup>0</sup>(k)* = *g<sub>ij</sub><sup>0</sup>**c<sub>i</sub>(k)*. Equation (4) is as followed.

$$g^0(k) = [g_{ij}^0 c_i(k)] \tag{4}$$

For the threshold *k*, two approaches can be employed to define *k*, including the number of dimensions deprived and the deprivation weight score. If the threshold is set too low, poverty may be overestimated as the number of dimensions increases (e.g., individuals or households who are deprived at least one dimension are regarded as multidimensional poor). If the threshold is set too high, poverty may be underestimated because of high restrictiveness (e.g., individuals or households who are deprived in all dimensions are treated as multidimensional poor). Thus, other intermediate values for *k* might be more appropriate (Nasri and Belhadj 2017). Generally, if the total score of deprivation weight is greater than 0.3, this person is considered to be multidimensional poor (Alkire and Foster 2011). It also turns out that 0.3 is a clear cut-off value in this study (see Appendix Fig. A1).

Based on the identification, the headcount ratio of MP can be obtained (H). That is, the number of populations who are MP (*q*)

divided by the total number of people (N), reflecting the size of the poverty. Equation (5) is:

$$H = \frac{\sum_{i=1}^N c_i(k)/N = q/N \tag{5}$$

It is also able to derive the average deprivation share of multidimensional poor people (A). That is, the number of deprived dimensions among multidimensional poor people divided by the number of multidimensional poor people. Equation (6) is:

$$A = |g^0(k)|/q = \frac{\sum_{j=1}^D \sum_{i=1}^N g_{ij}^0(k)/q \tag{6}$$

In turn, the MPI (*M<sub>0</sub>*), which is the adjusted headcount ratio of MP, is derived. Equation (7) is:

$$M_0 = \sum_{j=1}^D \sum_{i=1}^N g_{ij}^0(k)/N = H \times A \tag{7}$$

Where, the contribution of dimension *j* to MPI is equal to the proportion of dimension *j* in MPI. Equation (8) is:

$$C_j = M_{0j}/M_0 \tag{8}$$

Building on the above, index disaggregation can be performed for expressing subgroups of MPI over time and across regions. The formula is as follows, where G and g denote the number of people in different subgroups. Equation (9) is:

$$M(k) = \frac{G}{N} MG(k) + \frac{g}{N} Mg(k) \tag{9}$$

According to the duration of MP, people are classified into three groups, i.e., never poverty, temporary poverty and chronic poverty. Assume that *p<sub>k</sub><sup>i</sup>* denotes the overall poverty status of individual *i* in T period. *T<sub>k</sub><sup>i</sup>* denotes the poverty time of individual *i* in T period, and *t* is the time threshold for determining the poverty types. When individual *i* has 0 years in period T, *i* is never poor. When duration is from 0 to *t*, *i* is temporary poor. If duration is over *t*, *i* is chronic poor. Based on the selection criteria for *k* values, we considered the

**Table 2 The overall results of multidimensional poverty in different subgroups in this study ( $k = 0.3, N = 133,557$ ).**

	M <sub>0</sub>		H		A		95%CI		Pop share
	Value	Relative Δ (%)	Value	Relative Δ (%)	Value	Relative Δ (%)	Absolute Δ	Relative Δ (%)	
Total	0.16 (0.001)	0.161	0.387 (0.001)	0.389	0.415 (0)	0.416	0.008*** (0.0009)	1.95	1
Gender									
Women	0.18 (0.001)	0.178	0.43 (0.002)	0.433	0.418 (0.001)	0.419	0.008*** (0.0009)	1.95	0.498
Men	0.141 (0.001)	0.14	0.344 (0.002)	0.347	0.41 (0.001)	0.412	0.007*** (0.0009)	7.87	0.502
Rural	0.211 (0.001)	0.209	0.497 (0.002)	0.493	0.425 (0.001)	0.426	0.031*** (0.0009)	7.87	0.512
-urban	0.107 (0.001)	0.105	0.271 (0.002)	0.268	0.394 (0.001)	0.396	0.009*** (0.0013)	2.14	0.488
Rural	0.237 (0.001)	0.234	0.351 (0.003)	0.357	0.429 (0.001)	0.431	0.009*** (0.0013)	2.14	0.488
Urban	0.122 (0.001)	0.12	0.307 (0.003)	0.302	0.397 (0.001)	0.399	0.007*** (0.0012)	1.79	0.508
Urban	0.091 (0.001)	0.089	0.234 (0.002)	0.229	0.39 (0.001)	0.388	0.032*** (0.0013)	8.06	0.492
Rural women vs. Urban women									
Rural women									
Urban women									
Rural women vs. Urban men									
Rural women									
Urban men									

\*\*\*p < 0.001. \*\*p < 0.01. \*p < 0.05. Standard errors in brackets.

intermediate values in this duration to avoid the shortage of extreme thresholds. When  $t > 2$  in 5 rounds data, there is a visible change between temporary poverty and chronic poverty (see Appendix Fig. A2). Therefore, this study adopted 2 as the  $t$  critical value to decompose the poverty types. Equation (10) is:

$$p_k^i = \begin{cases} 0, & \text{if } T_k^i = 0 \\ 1, & \text{if } 0 < T_k^i \leq t \\ 2, & \text{if } t < T_k^i \leq T \end{cases} \quad (10)$$

**Results**

**Multidimensional poverty in different subgroups.** Based on the pooled data, the results of MP were captured for comparative analysis (see Table 2). The overall picture is not encouraging with a high headcount ratio ( $H = 0.387, M_0 = 0.16, A = 0.15$ ). The male-female comparative data showed that women ( $H = 0.43, M_0 = 0.18, A = 0.418$ ) were more likely to be multidimensionally poor than men ( $H = 0.344, M_0 = 0.141, A = 0.41$ ). Women’s MPI was relatively 27.66% higher than men’s. In the urban-rural results, rural populations were exposed to higher risks of MP ( $H = 0.497, M_0 = 0.211, A = 0.452$ ). And rural headcount ratios were relatively 83.39% higher than urban headcount ratios. Rural women had the highest risk of MP in four subgroups ( $H = 0.551, M_0 = 0.237, A = 0.429$ ), i.e., rural women, rural men, urban women and urban men. The censored headcount ratio of rural females was relatively 26.74% higher than that of rural males, 94.26% higher than that of urban females and 160.44% higher than that of urban males, respectively.

The deprivation ratios of indicators showed a significant gender inequality with a preference of female disadvantage (see Table 3). Overall, pension insurance accounted for the highest share, regardless of rural-urban groups or male-female groups. In addition to the indicators of drinking water, cooking fuels and life satisfaction, females were more deprived than males. For example, educational deprivation rates were much higher for females than for males, especially with a 29.8% gap in rural areas. Likewise, the differences in nutritional deprivation exceeded 50%. However, the divergence in housing deprivation was not significant, although women remained disadvantaged. Perhaps this gender difference is weakened by the fact that housing rights belongs to family members.

There were also rural-urban differences and gender disparities in the contribution of dimensions to MPI (see Table 4). As a whole, rural residents focused on economic income (0.12) and living standards (0.12), while urban residents paid more attention to subjective wellbeing (0.135) and social welfare (0.232). From the perspective of gender comparison, the contribution ratios of education, health and subjective wellbeing were larger among women. However, the contribution ratios of income, social welfare and living standards were higher among men. For example, the contribution of health dimension to women’s MPI relatively exceeded the contribution to men’s MPI by 17%. Economic status relatively contributed 15.97% more to men than to women. Compared with other subgroups, the education dimension had the highest contribution rate to rural women’s MPI, at 35.4%.

**Multidimensional poverty of rural women.** On the basis of the above, this study analyzed rural women’s data to portray the static and dynamic characteristics of their MP in detail ( $N = 8950$ ). The results reported demographic features and the spatio-temporal differences.

*Demographic features.* The data showed that old-aged rural women had a higher risk of poverty (see Table 5). Rural women

**Table 3 The proportion of deprivation indicators for different subgroups (k = 0.3, N = 133,557, %).**

Dimension	Indicator	Total					Rural					Urban				
		Women(w)	Men(m)	Total	Absolute Δ	Relative Δ	Women(w)	Men(m)	Total	Absolute Δ	Relative Δ	Women(w)	Men(m)	Total	Absolute Δ	Relative Δ
Economic Status	Income	11.56	11.17	11.36	0.39* (0.002)	3.46	16.70	16.02	16.35	0.69* (0.003)	4.30	6.37	5.89	6.13	0.48* (0.002)	8.16
Education	Years of education	47.81	37.34	42.55	10.46*** (0.002)	28.02	61.90	47.69	54.63	14.21*** (0.004)	29.80	33.60	26.06	29.89	7.54*** (0.004)	28.93
Health	Nutrition	12.17	7.78	9.96	4.39*** (0.002)	56.50	14.27	9.26	11.71	5** (0.003)	54.01	10.05	6.15	8.13	3.90*** (0.002)	63.38
	Self-rated health	29.67	23.38	26.51	6.29*** (0.003)	26.89	31.88	24.99	28.36	6.89*** (0.004)	27.57	27.43	21.62	24.57	5.81*** (0.004)	26.87
	Chronic diseases	16.22	13.37	14.79	2.85*** (0.002)	21.30	16.28	13.00	14.60	3.28*** (0.003)	25.24	16.15	13.77	14.98	2.38*** (0.003)	17.29
Social Welfare	Medical insurance	9.74	8.79	9.26	0.94*** (0.002)	10.71	7.81	6.88	7.33	0.93*** (0.002)	13.58	11.68	10.89	11.29	0.79** (0.003)	7.29
	Pension insurance	72.19	69.95	71.06	2.24*** (0.003)	3.20	72.56	71.93	72.24	0.63(0.003)	0.87	71.81	67.78	69.83	4.03*** (0.004)	5.94
Living Standards	Drinking water	4.49	4.87	4.68	-0.37** (0.001)	-7.64	7.54	7.87	7.71	-0.33 (0.002)	-4.24	1.42	1.59	1.5	-0.16 (0.001)	-10.33
	Cooking fuel	34.79	36.10	35.45	-1.31*** (0.003)	-3.64	53.28	53.97	53.64	-0.69 (0.004)	-1.28	16.15	16.61	16.38	-0.47 (0.003)	-2.82
	Housing asset	14.69	14.65	14.67	0.05 (0.002)	0.32	9.15	9.02	9.08	0.14 (0.002)	1.50	20.28	20.78	20.53	-0.50 (0.003)	-2.42
Subjective Wellbeing	Life satisfaction	9.74	10.70	10.23	-0.96*** (0.002)	-8.96	10.28	11.29	10.80	-1.00*** (0.002)	-8.88	9.20	10.07	9.63	-0.87*** (0.002)	-8.61
	Depression	30.87	23.74	27.29	7.13*** (0.003)	30.03	34.18	26.62	30.31	7.56*** (0.004)	28.38	27.53	20.59	24.11	6.94*** (0.003)	33.69

\*\*\*p < 0.001. \*\*p < 0.01. \*p < 0.05. Standard errors in brackets. Absolute = w-m. Relative = (w-m)/w.

**Table 4 The contribution ratio of indicators in the MPI for different subgroups ( $k = 0.3, N = 133,557$ ).**

Dimension	Indicator	Total				Rural				Urban						
		Women(w)	Men(m)	Total	Absolute $\Delta$	Relative $\Delta$ (%)	Women(w)	Men(m)	Total	Absolute $\Delta$	Relative $\Delta$ (%)	Women(w)	Men(m)	Total	Absolute $\Delta$	Relative $\Delta$ (%)
Economic Status		0.1	0.119	0.108	-0.019* (0.0003)	-15.97	0.111	0.131	0.12	-0.020* (0.001)	-15.27	0.077	0.09	0.083	-0.013* (0.0003)	-14.44
Education	Income	0.1	0.119	0.108			0.111	0.131	0.12			0.077	0.09	0.083		
	Years of education	0.352	0.335	0.344	0.017*** (0.001)	5.07	0.354	0.336	0.346	0.018*** (0.001)	5.36	0.346	0.333	0.341	0.013*** (0.001)	3.90
Health		0.117	0.1	0.11	0.017*** (0.0002)	17.00	0.112	0.095	0.104	0.017*** (0.0003)	17.89	0.128	0.111	0.121	0.017*** (0.0003)	15.32
	Nutrition	0.021	0.018	0.02			0.023	0.019	0.021			0.018	0.016	0.017		
Social Welfare	Self-rated health	0.063	0.054	0.059			0.059	0.051	0.055			0.071	0.061	0.067		
	Chronic diseases	0.033	0.028	0.031			0.03	0.025	0.028			0.039	0.034	0.037		
Living Standards		0.2	0.209	0.203	-0.009*** (0.0003)	-4.31	0.185	0.195	0.19	-0.010*** (0.0004)	-5.13	0.228	0.238	0.232	-0.010*** (0.0004)	-4.20
	Medical insurance	0.026	0.027	0.026			0.019	0.02	0.02			0.039	0.042	0.04		
Subjective Wellbeing	Pension insurance	0.174	0.182	0.177			0.166	0.175	0.17			0.189	0.196	0.192		
	Drinking water	0.01	0.011	0.01			0.013	0.015	0.014			0.003	0.004	0.003		
Subjective Wellbeing	Cooking fuel	0.075	0.084	0.079			0.09	0.097	0.093			0.047	0.055	0.05		
	Housing asset	0.02	0.021	0.02			0.012	0.013	0.013			0.034	0.037	0.035		
Subjective Wellbeing		0.127	0.122	0.125	0.005*** (0.0003)	4.10	0.122	0.118	0.12	0.004*** (0.0004)	3.39	0.137	0.132	0.135	0.005*** (0.0004)	3.79
	Life satisfaction	0.034	0.042	0.038			0.031	0.038	0.034			0.041	0.051	0.045		
	Depression	0.093	0.08	0.087			0.091	0.08	0.086			0.096	0.081	0.09		

\*\*\* $p < 0.001$ . \*\* $p < 0.01$ . \* $p < 0.05$ . Standard errors in brackets. Absolute = w-m. Relative = (w-m)/w.



**Table 5 The decomposition results of rural women's MP ( $k = 0.3, N = 8950$ ).**

	M <sub>0</sub>			H			A			Pop share			
	Value	95%CI	Absolute Δ	Relative Δ (%)	Value	95%CI	Absolute Δ	Relative Δ (%)	Value	95%CI	Absolute Δ	Relative Δ (%)	
	Total	0.207 (0.002)	0.202	0.211		0.496 (0.005)	0.485	0.506		0.417 (0.002)	0.414	0.42	1
Age	0.184 (0.002)	0.179	0.189		0.447 (0.006)	0.436	0.459		0.411 (0.002)	0.408	0.414	0.812	
60+	0.334 (0.006)	0.323	0.345	0.15*** (0.005)	0.764 (0.012)	0.741	0.787	0.317*** (0.014)	70.92	0.437 (0.003)	0.43	0.444	0.188
Marital status	0.217 (0.009)	0.2	0.234		0.49 (0.018)	0.454	0.527		0.443 (0.006)	0.431	0.454	0.186	
No spouse	0.206 (0.002)	0.201	0.211	-0.011*** (0.006)	0.496 (0.006)	0.485	0.507	0.006 (0.019)	1.22	0.415 (0.002)	0.412	0.418	0.814
With spouse	0.364 (0.009)	0.348	0.381		0.775 (0.016)	0.743	0.807		0.47 (0.005)	0.46	0.48	0.092	
Confidence in the future	0.194 (0.002)	0.189	0.199	-0.17*** (0.006)	0.473 (0.005)	0.462	0.484	-0.302*** (0.02)	-38.97	0.41 (0.002)	0.407	0.413	0.908
Yes	0.21 (0.004)	0.203	0.217		0.499 (0.008)	0.484	0.515		0.42 (0.002)	0.416	0.425	0.436	
Poor	0.204 (0.003)	0.198	0.21	-0.006 (0.003)	0.492 (0.007)	0.479	0.506	-0.007 (0.011)	-1.40	0.415 (0.002)	0.411	0.419	0.564
Good													

\*\*\*p < 0.001. \*\*p < 0.01. \*p < 0.05. Standard errors in brackets.

aged over 60 ( $H = 0.764, A = 0.437, M_0 = 0.334$ ) were more multidimensionally poor than those aged less 60 ( $H = 0.447, A = 0.411, M_0 = 0.184$ ), with a relative higher risk of 81.52%. Similarly, rural women with spouses had a lower risk of poverty than those without spouses. And rural women who had confidence in the future were less likely to be deprived than those who had no confidence. However, the difference was no significant between the government performance comparisons, although the good performance had a positive impact on the poverty reduction. The reason may be that the evaluation of government performance is not specifically targeted at rural female's poverty alleviation, resulting in scattered governance effects.

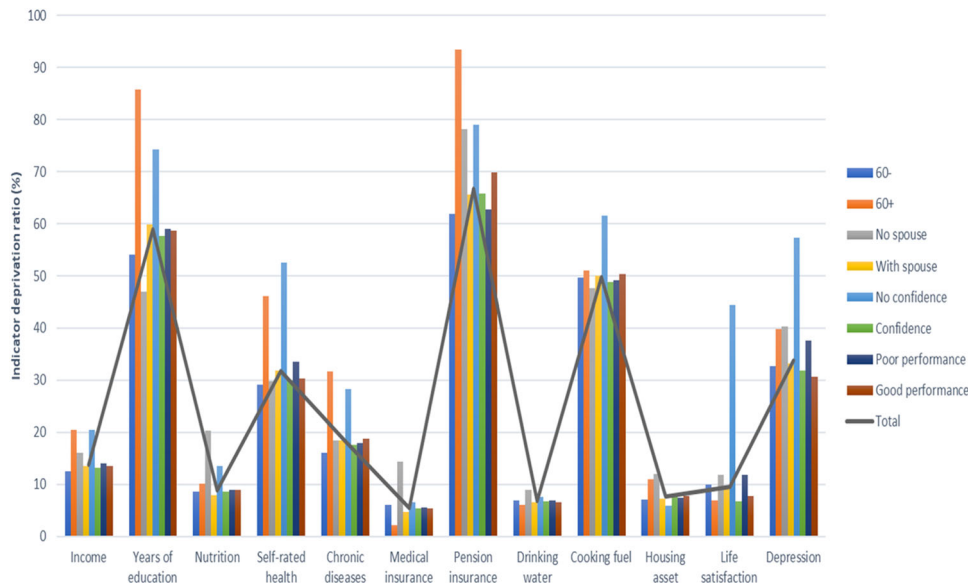
According to the results of indicator deprivation (see Fig. 1), the deprivation rates of older rural women were much higher than those of younger rural women with the exception of drinking water, medical insurance and life satisfaction. And the deprived ratios of schooling, pension insurance were more than 85% for older rural women, which exceeded the overall level. And rural women who had no confidence were highly deprived in the indicators of self-rate health, life satisfaction and depression. Especially, the deprivation rate of life satisfaction and depression was up to 44.38% and 57.27%, respectively.

In terms of indicator contribution ratios in MPI (see Fig. 2), education dimension had the highest contribution in all groups (over 0.3), followed by social welfare (over 0.16). And the contribution of subjective wellbeing was the largest among rural women without confidence in the future (0.198). The indicators of life satisfaction and depression contributed 0.086 and 0.112, respectively. In addition, the deprivation intensity of economic status was greater for rural women without spouses (0.115) than other subgroups. This indicated that they were more vulnerable to economic poverty as they lacked financial support from spouses or families.

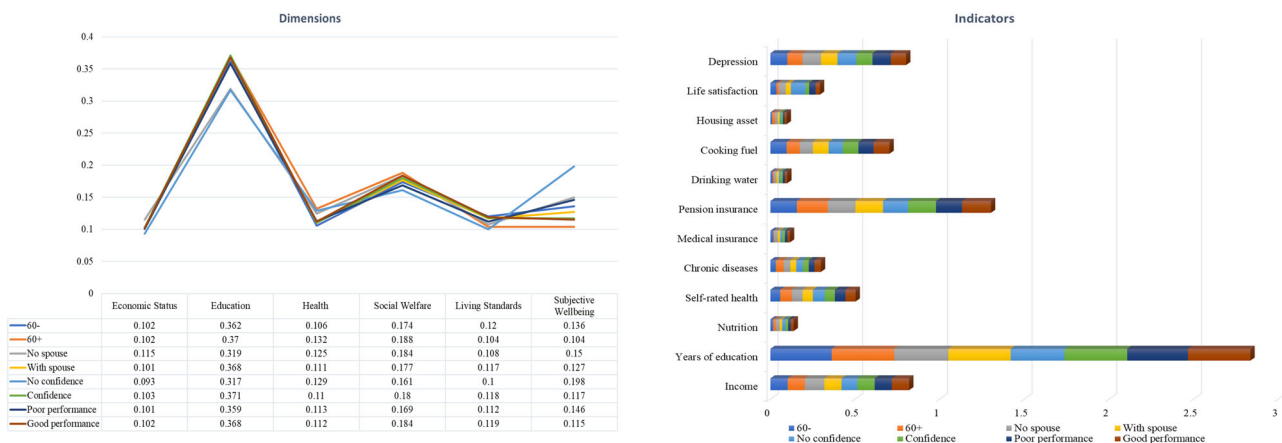
*Spatial distribution features.* According to the decomposition results of MPI (see Table 6), the regional differences were significant ( $p < 0.001$ ). The highest censored headcount ratio of poverty was found among rural women in the Western Region ( $H = 0.596, A = 0.426, M_0 = 0.254$ ). It was 44.32% higher than that of rural women in the Eastern Region ( $H = 0.43, A = 0.409, M_0 = 0.176$ ), and 28.28% higher than that of rural women in the Central Region ( $H = 0.476, A = 0.416, M_0 = 0.198$ ).

And education, pension insurance, cooking fuel and depression accounted for a larger share of deprivation in three regions (see Table 7). According to the comparison results, the absolute difference in the deprivation rate of cooking fuel was the largest between Eastern Region and Western Region (absolute values = 25.896). Meanwhile, the relative difference in water deprivation rates was as high as 395%. And rural women in the western areas faced serious difficulties with cleaning water and fuels. The reason may be that the western region in China is mostly dominated by mountains, plateaus or deserts. The natural conditions so uninhabitable that it results in worse living conditions in rural areas. However, there was no significant difference in life satisfaction between western rural areas and eastern rural areas. And rural women in the Eastern Region were more deprived in medical insurance (6.39%), pension insurance (70.8%) and housing asset (9.37%). One possible explanation is that the population density in the eastern China is high, resulting in fierce competition for resources. This has a stronger crowding-out effect on rural women in Eastern Region.

Based on the findings of contribution ratio (see Table 8), there were significant regional differences in the contribution of dimensions to rural women's MPI. Education, social welfare and subjective wellbeing contributed more to the MPI than



**Fig. 1 Indicator deprivation rates of rural women in different subgroups (k = 0.3, N = 8950).** The plot shows the deprivation percentage of each indicator among different rural women. The X-axis shows the categories of the indicators, with different groups represented by coloured bars, and the Y-axis shows the deprivation rates of the indicators from 0 to 100%.



**Fig. 2 Contributions of dimensions and indicators to rural women's MPI (k = 0.3, N = 8950).** Dimensions represent the contribution of each dimensional deprivation of different rural women to their MPI. Where X-axis is dimensional categories, different coloured lines indicate different groups, and Y-axis is dimensional contribution power, ranging from 0 to 0.4. Indicators represent the contribution of each indicator deprivation of different rural women to their MPI. Where Y-axis is the indicator category, different coloured cumulative bars indicate different groups, and X-axis is the dimensional contribution power, ranging from 0 to 3.

economic dimension. For example, the educational dimension made the highest contribution, exceeding 35% in all three regions. And compared with rural women in the Western Region, social welfare played a greater role in rural women's MPI in the Eastern Region (19.4%), while subjective wellbeing played a smaller role (12.9%). Living standards had a greater impact on rural women in the Western Region, with a relative increase of 32.35%. It can be indicated that rural women in the western areas were troubled by material living conditions.

*Temporal distribution features.* In view of the temporal results from 2010 to 2020, rural women's MPI was gradually decreased (see Table 6). The headcount ratios dropped from 0.588 in 2010 to 0.401 in 2020. And the censored headcount ratios decreased by 34.8% relatively between 2010 and 2020. The intensity of deprivation fell from 0.425 in 2010 to 0.407 in 2020.

In the results of index deprivation rate (see Table 7), half of indicators showed significant decline, including income, nutrition, medical insurance, pension, fuel and life satisfaction. It indicated that those indicators of rural women were improved over years. For example, the deprivation rate of pension insurance changed from 100% in 2010 to 44.06% in 2020, with a relative decrease of 55.04%. And the relative decrease rate of medical insurance was as high as 96.15%. One reason may be that social welfare systems has been improved during 10 years in China. The coverage rate of medical and pension insurance has gradually increased in rural areas, such as the Rural Basic Pension Insurance and the New Rural Cooperative Medical Care (Shen and Li 2022). Conversely, another half of indicators showed an upward trend, including education, self-rated health, chronic diseases, drinking water, housing asset and depression. That is, those indicators of rural women were deprived more than before.

**Table 6 The decomposition results of spatial and temporal characteristics among rural women ( $k = 0.3, N = 8950$ ).**

	M <sub>0</sub>			H			A			Pop share						
	Value	95%CI	Absolute Δ (%)	Value	95%CI	Absolute Δ (%)	Value	95%CI	Absolute Δ (%)	Value	95%CI	Absolute Δ (%)	Relative Δ (%)			
Spatial data	Eastern Region	0.176 (0.004)	0.169	0.183	0.078*** (0.004)	44.32	0.43 (0.008)	0.414	0.447	0.166*** (0.013)	0.409 (0.003)	0.403	0.414	0.017*** (0.046)	4.16	0.39
	Central Region	0.198 (0.004)	0.19	0.206	0.056*** (0.004)	28.28	0.476 (0.01)	0.457	0.495	0.12*** (0.013)	0.416 (0.003)	0.41	0.422	0.010*** (0.042)	2.40	0.297
	Western Region	0.254 (0.004)	0.245	0.262			0.596 (0.009)	0.578	0.614		0.426 (0.003)	0.421	0.431			0.313
	Temporal data	0.25 (0.005)	0.24	0.26	-0.087*** (0.005)	-34.8	0.588 (0.011)	0.566	0.61	-0.187*** (0.016)	0.425 (0.003)	0.418	0.431	-0.018*** (0.056)	-4.24	0.228
						0.261 (0.005)	0.251	0.271		0.426 (0.003)	0.42	0.432			0.21	
						0.184 (0.005)	0.174	0.195		0.42 (0.004)	0.413	0.427			0.201	
						0.163 (0.005)	0.153	0.172		0.397 (0.003)	0.391	0.404			0.187	
						0.163 (0.005)	0.153	0.173		0.407 (0.004)	0.4	0.414			0.184	

\*\*\*p < 0.001. \*\*p < 0.01. \*p < 0.05. Standard errors in brackets. In the spatial data, Absolute = value<sub>Western</sub> - value<sub>Eastern</sub>; Relative = (value<sub>Western</sub> - value<sub>Eastern</sub>) / value<sub>Eastern</sub>. In the temporal data, Absolute = value<sub>2020</sub> - value<sub>2010</sub>; Relative = (value<sub>2020</sub> - value<sub>2010</sub>) / value<sub>2010</sub>.

Especially, the deprived ratio of self-rated health and depression relatively increased by 83.74% and 49.89%, respectively. This significant change indicated that the health status of rural women is urgent to be improved. However, the differences of education and drinking water were insignificant. This also illustrated that the difficulties of education and water were not effectively addressed among rural women.

According to the results of contribution ratio (see Table 8), dimensions in economic status, social welfare and living standards showed a downward trend from 2010 to 2020. Conversely, dimensions in education, health and subjective wellbeing showed an upward trend, with a relative increase of 14.96%, 67.86% and 32.43%, respectively. That is to say, the material factors were becoming less important for rural women's MPI over time. However, non-material factors had an increasingly important contribution to rural women's MPI. That is probably because the government has achieved success in fighting absolute poverty. They are able to pursue a higher quality of life. The remaining details not described are given in Tables 6–8.

*Spatio-temporal interaction features.* Based on the spatio-temporal interaction data (see Fig. 3), rural women's MPI has decreased over time in all regions. Especially in the Western Region, the headcount ratio of rural women dropped sharply from 74.3% in 2010 to 44.8% in 2020. And the censored headcount ratio reduced from 23% in 2010 to 17.8% in 2020. In terms of index deprivation rate, other indicators had undergone significant changes, except for education, chronic diseases and drinking water in the Western Region. And the contributions of economy, social welfare and living standards to MPI had become significantly weaker over time. Due to space limitations, no further details are shown in Appendix Tables A7–A8.

*The dynamics of multidimensional poverty.* According to the time cutoff value ( $t = 2$ ), the results suggested that 26% of rural women were never poor, 26.02% of rural women were temporary poor, and the proportion of chronic poverty was up to 47.77% in total (see Table 9). Namely, 74% of rural women were likely to be at the risk of temporary or chronic poverty. And the proportion of rural women who were never poor was the highest in the Eastern Region (47.61%), followed by the Central Region (33.38%), and the lowest in the Western Region (19.01%). Nevertheless, rural women in Western Region ranked the first in the proportion of chronic poverty (38.11%), while those in Eastern Region ranked the least (33.55%). In the Central Region, the distribution of three types was relatively balanced. And never poverty, temporary poverty and chronic poverty accounted for 33.38%, 28.55% and 28.4%, respectively. Chronic poverty between regions should be noted to improve the effectiveness of poverty governance.

**Sensitivity to threshold  $k$  and  $t$ .** In the results of sensitivity analysis (see Fig. 4), rural women's MPI decreased as threshold  $k$  increased in all regions from 2010 to 2020. When  $k > 0.3$ , index values changed drastically. When  $k > 0.6$ , the incidence of rural women's MP was almost zero. Under the equal level of  $k$ , the incidence and intensity of rural women's MP were the highest in Western Region and the lowest in Eastern Region. Similarly, we also tested the sensitivity of the time threshold  $t$  (see Fig. 5). The results showed that 2 was a clear cut-off  $t$  value. When  $t > 2$ , the shares of chronic poverty and temporary poverty changed dramatically. The share of chronic poverty gradually approached 0, and the share of temporary poverty gradually approached 0.8 in total. This trend applied equally to different regions, although the fluctuations were larger in the Western Region. Therefore, appropriate thresholds can prevent insufficient validity of evidence caused by excessive evaluation errors.

**Table 7 Deprivation rates of multidimensional poverty indicators for rural women in the spatial and temporal data (k = 0.3, N = 8950, %).**

	Spatial data				Temporal data							Relative Δ	Absolute Δ	Relative Δ
	Eastern Region	Central Region	Western Region	Relative Δ	2010	2012	2014	2018	2020	Absolute Δ				
Income	11.15	13.79	16.94	51.99	17.98	17.26	17.72	5.78	8.50	-9.481*** (0.011)	-52.74			
Years of education	53.21	58.23	66.44	24.87	57.32	61.71	59.11	58.08	57.83	0.509 (0.165)	0.89			
Nutrition	7.08	7.51	12.44	75.74	11.40	10.99	8.58	6.26	6.49	-4.909*** (0.009)	-43.05			
Self-rated health	29.94	30.84	34.81	16.26	19.06	38.93	30.70	36.26	35.01	15.957*** (0.015)	83.74			
Chronic diseases	15.70	18.48	21.59	37.48	16.28	14.07	20.00	22.30	19.96	3.683** (0.013)	22.62			
Medical insurance	6.39	4.77	4.97	-22.25	12.58	7.06	5.63	0.12	0.49	-12.098*** (0.008)	-96.15			
Pension	70.80	68.30	60.04	-15.20	100	96.44	40.72	43.77	44.96	-55.04*** (0.013)	-55.04			
Drinking water	2.72	4.96	13.47	395.00	5.14	5.15	9.19	7.99	6.55	1.417 (0.08)	27.59			
Cooking fuel	40.26	45.19	66.15	64.33	64.05	53.64	52.03	41.44	34.77	-29.278*** (0.016)	-45.71			
Housing asset	9.37	6.27	6.83	-27.15	6.42	6.75	6.30	9.12	10.13	3.713*** (0.009)	57.83			
Life satisfaction	9.14	9.09	10.37	13.40	12.58	15.83	8.52	5.19	4.13	-8.457*** (0.009)	-67.21			
Depression	31.15	29.56	40.92	31.39	28.10	31.12	28.41	40.67	42.11	14.017*** (0.016)	49.89			

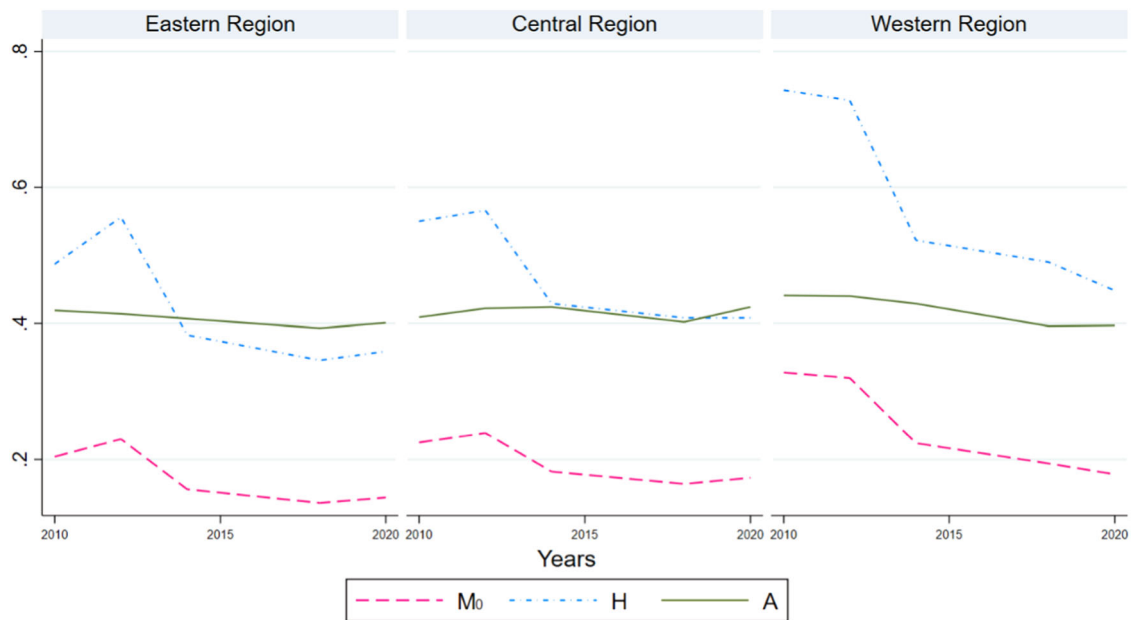
\*\*\*p < 0.001. \*\*p < 0.01. \*p < 0.05. Standard errors in brackets. In the spatial data, Absolute = value<sub>Western</sub> - value<sub>Eastern</sub>, Relative = (value<sub>Western</sub> - value<sub>Eastern</sub>) / value<sub>Eastern</sub>. In the temporal data, Absolute = value<sub>2020</sub> - value<sub>2010</sub>, Relative = (value<sub>2020</sub> - value<sub>2010</sub>) / value<sub>2010</sub>.

**Table 8 Contribution rates of indicators in rural women's MPI in the spatial and temporal data (k = 0.3, N = 8950).**

Dimension	Indicator	Spatial data					Temporal data						
		Eastern Region	Central Region	Western Region	Absolute Δ	Relative Δ (%)	2010	2012	2014	2018	2020	Absolute Δ	Relative Δ (%)
Economic status		0.096	0.107	0.104	0.008*** (0.001)	8.33	0.115	0.105	0.137	0.054	0.079	-0.036*** (0.002)	-31.30
Education	Income	0.096 0.37	0.107 0.369	0.104 0.355	-0.015*** (0.002)	-4.05	0.115 0.341	0.105 0.351	0.137 0.363	0.054 0.401	0.079 0.392	0.051 (0.003)	14.96
	Years of education	0.37	0.369	0.355			0.341	0.351	0.363	0.401	0.392		
Health		0.109	0.114	0.114	0.005*** (0.001)	4.59	0.084	0.105	0.12	0.139	0.141	0.057*** (0.001)	67.86
	Nutrition	0.013	0.014	0.019			0.018	0.016	0.017	0.012	0.013		
	Self-rated health	0.063	0.063	0.058			0.037	0.065	0.063	0.077	0.08		
Chronic diseases		0.033	0.037	0.037			0.029	0.024	0.04	0.05	0.048		
		0.194	0.185	0.157	-0.037*** (0.001)	-19.07	0.223	0.208	0.134	0.133	0.137	-0.086*** (0.001)	-38.57
Social Welfare	Medical insurance	0.018	0.013	0.013			0.027	0.015	0.017	0.001	0.002		
	Pension insurance	0.176	0.172	0.144			0.196	0.193	0.117	0.132	0.135		
Living Standard		0.102	0.107	0.135	0.033*** (0.001)	32.35	0.126	0.107	0.12	0.122	0.103	-0.023*** (0.001)	-18.25
	Drinking water	0.005	0.01	0.022			0.01	0.009	0.018	0.018	0.014		
Cooking fuel		0.08	0.088	0.105			0.107	0.089	0.093	0.087	0.072		
	Housing asset	0.017	0.009	0.008			0.009	0.009	0.009	0.017	0.017		
Subjective Wellbeing	Life satisfaction	0.129	0.117	0.136	0.007*** (0.001)	5.43	0.111	0.124	0.126	0.152	0.147	0.036** (0.002)	32.43
	Depression	0.032	0.03	0.03			0.034	0.042	0.031	0.019	0.015		
		0.097	0.087	0.106			0.077	0.082	0.095	0.133	0.132		

\*\*\*p < 0.001. \*\*p < 0.01. \*p < 0.05. Standard errors in brackets. In the spatial data, Absolute = value<sub>Western</sub> - value<sub>Eastern</sub>, Relative = (value<sub>Western</sub> - value<sub>Eastern</sub>) / value<sub>Eastern</sub>. In the temporal data, Absolute = value<sub>2020</sub> - value<sub>2010</sub>, Relative = (value<sub>2020</sub> - value<sub>2010</sub>) / value<sub>2010</sub>.





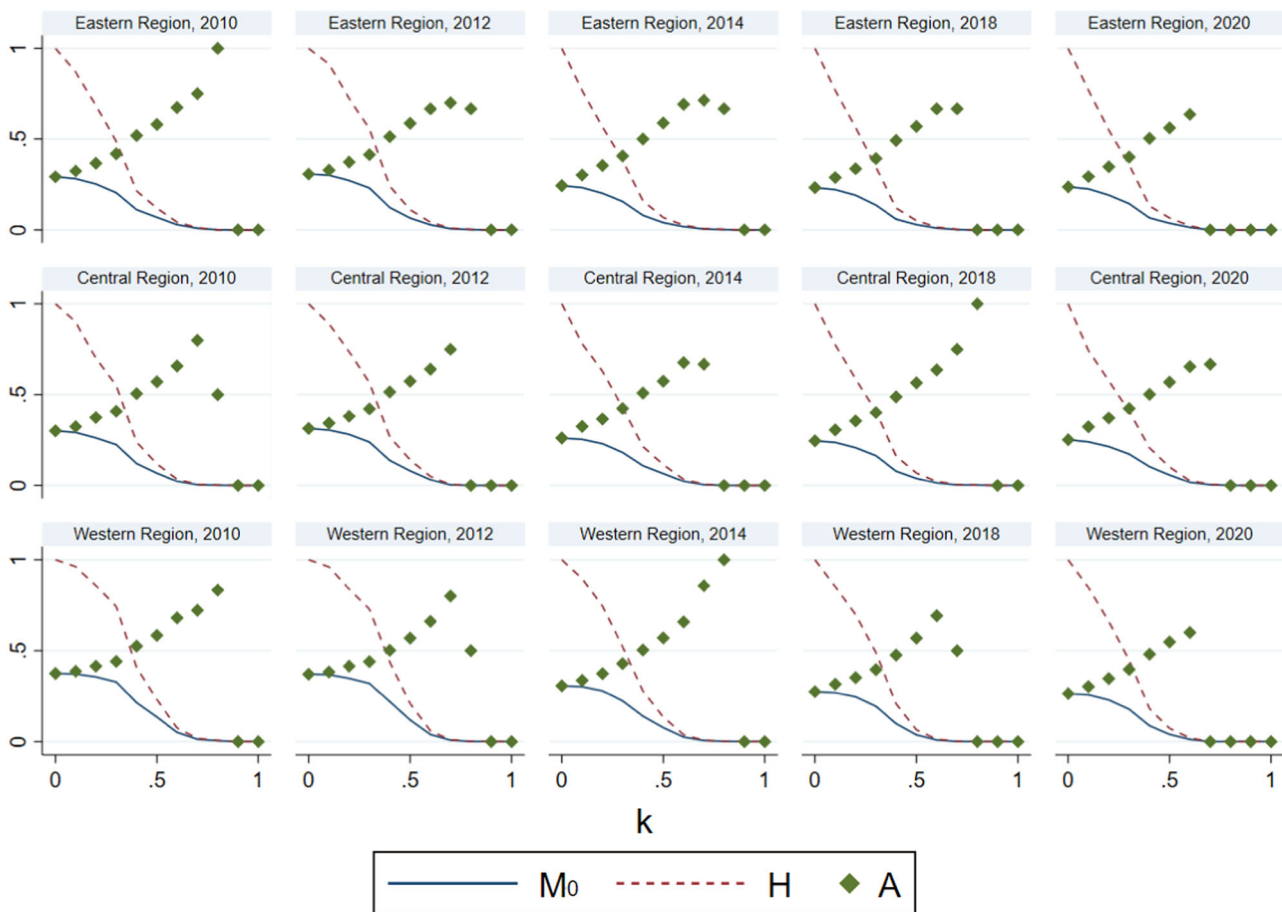
**Fig. 3 Spatio-temporal interaction characteristics of rural women's MPI ( $k = 0.3, N = 8950$ ).** The picture represents the rural women's MPI in different regions, including eastern region, central region and western region, respectively. The X-axis shows the time range (2010–2020), and the Y-axis shows the corresponding values of  $M_0$ ,  $H$  and  $A$ .

**Table 9 Descriptive statistics of multidimensional poverty types among rural women ( $t = 2, k = 0.3, N = 8950$ ).**

	Never poverty	Temporary poverty	Chronic poverty	Total
Eastern Zone (N)	1117	941	1432	3490
Row percentage (%)	32.01	26.96	41.03	100
Column percentage (%)	47.61	40.4	33.5	38.99
Total percentage (%)	12.48	10.51	16	38.99
Central Zone (N)	783	665	1214	2662
Row percentage (%)	29.41	24.98	45.6	100
Column percentage (%)	33.38	28.55	28.4	29.74
Total percentage (%)	8.75	7.43	13.56	29.74
Western Region Zone (N)	446	723	1629	2798
Row percentage (%)	15.94	25.84	58.22	100
Column percentage (%)	19.01	31.04	38.11	31.26
Total percentage (%)	4.98	8.08	18.2	31.26
Total (N)	2346	2329	4275	8950
Row percentage (%)	26.21	26.02	47.77	100
Column percentage (%)	100	100	100	100
Total percentage (%)	26.21	26.02	47.77	100

**Robustness results.** Referring to the measurement of OPHI<sup>5</sup>, we used three dimensions (i.e., education, health and living standards) to conduct robustness testing. The overall results suggested that from a gender perspective, the risk of women's MP ( $M_0 = 0.242, H = 0.5, A = 0.485$ ) was significantly higher than that of men's MP ( $M_0 = 0.188, H = 0.401, A = 0.468$ ). From an urban-rural perspective, the rural population ( $M_0 = 0.281, H = 0.573, A = 0.49$ ) was more likely to be multidimensional poor than the urban population ( $M_0 = 0.146, H = 0.322, A = 0.453$ ). Under the dual pressure of gender and urban-rural areas, rural women still had the largest MPI ( $M_0 = 0.32, H = 0.641, A = 0.499$ ), which was relatively higher than that of rural males (31.15%), urban females (93.94%) and urban males (153.97%), respectively. In the results of rural women, there were significant differences in spatio-temporal distribution. That is, the risk of rural women's MP was the highest in the Western Region, but the lowest in the Eastern Region. From 2010 to 2020, rural women's MPI showed a downward trend, with a

relative decrease of 0.69% (see Appendix Table A9). The deprivation rate of education indicator was still high, and its contribution to MPI was increasing over time (see Appendix Tables A10–A13 for other specific data). The proportion of chronic-poor rural women still ranked first (59.08%), followed by non-poor rural women (30.74%), and temporary-poor rural women account for 10.18% (see Appendix Table A14). It can be seen that the above conclusions are robust. Furthermore, the findings revealed that data from three dimensions overestimated the breadth and depth of rural women's MP compared with data from six dimensions. However, China has been in a new period of poverty governance. While ensuring basic survival needs, the government has paid more attention to the sharing of development results to enhance people's happiness and satisfaction. Therefore, the six-dimensional measurement is more likely to be in line with China's reality as it takes full account of material and non-material needs. And the results will be more meaningful for national policy development.



**Fig. 4 Changes of MPI with  $k$  in spatio-temporal data of rural women ( $N = 8950$ ).** The images represent the changes of rural women’s MP in the eastern region, central region and western region in 2010, 2012, 2014, 2018 and 2020 with increasing values of  $K$ , respectively. The X-axis represents  $K$ , ranging 0-1, and the Y-axis represents the corresponding values of  $M_0$ ,  $H$  and  $A$ .

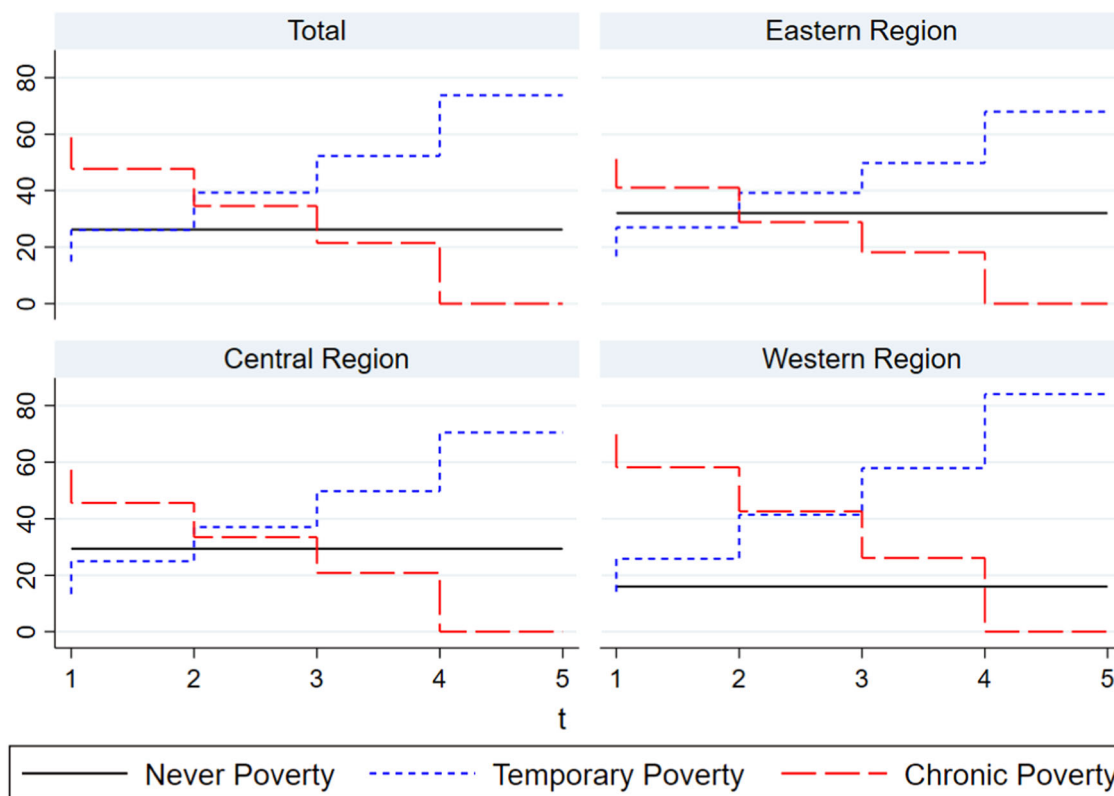
**Discussion**

Based on the A-F approach, the results showed that female impoverishment can be found in China. And the depth and breadth of rural women’s MP was the highest, which was consistent with previous findings (Yu et al. 2020; Zhang et al. 2021). One possible explanation is that the strong patriarchal culture in rural areas deprives opportunities and resources for female development (Jayachandran 2015). Housewifery and social exclusion further limit their dominance and voice. The real needs cannot be met so that rural women are at higher risk of poverty. Additionally, rural women’s educational attainment is more unsatisfactory than that of other control groups. This puts them at a disadvantage in social participation as well as contributes to their low status in the family and society (Biswal et al. 2020; Han et al. 2019). As a result, rural women’s lives are more vulnerable in China.

Moreover, the results suggested that the level of rural women’s MP varied depending on age, marriage and other factors. On the one hand, older rural women were more multidimensional poor than younger rural women. Perhaps it is the fact that ageing causes a decline in physical functioning, posing a threat to the survival and development of rural women. On the other hand, rural women with spouses were less multidimensional poor. One reason may be that intimate relationships provide them with additional supports, including emotional support, financial support and living care. Life risks are able to be shared by spouses and family members. However, single rural women have to deal independently with life difficulties, which enhances the likelihood of poverty.

Meanwhile, the data showed that confidence had a significant impact on rural women’s MP. And rural women with confidence in the future had a lower MPI than those without confidence. Confidence, as a positive psychological endowment, can be transformed into motivational behaviors, which promotes people to achieve desired goals through their own efforts (Wuepper and Lybbert 2017). Therefore, it is also a psychology capability for rural women to improve subjective wellbeing. From the perspective of government performance, rural women who perceived the government performance as good were less multidimensional poor. Nevertheless, there was no significant differences between good government performance and bad government performance in this research. One plausible explanation is that the well-performing government can address the needs of citizens to reduce poverty. However, rural women’s feedback may be influenced by other factors in non-specific measures. And the individual subjectivity of evaluation leads to a balance between merits and demerits in government performance.

The geospatial results showed that rural women in the Western Region were more disadvantaged than those in the Central Region and the Eastern Region. This may be largely influenced by nature environment and social conditions. On the one hand, previous studies have also found a high degree of overlap between ecological resource and poverty (Liu et al. 2017; Shepherd et al, 2013; Yan 2016; Zhu et al. 2022). And ecological environment is quite fragile in western areas, China, such as mountainous and desert areas, occasional earthquakes and droughts, etc.. This may increase the life vulnerability of rural women. On the other hand,



**Fig. 5 The percentages of poverty types with  $t$  among rural women in different regions ( $k = 0.3$ ,  $N = 8950$ ).** The picture shows the percentage of poverty types among rural women in general and in the three main regions as the  $t$ -value varies. The X-axis shows the range of  $t$  from 1 to 5, and the Y-axis shows the corresponding values for never poverty, temporary poverty and chronic poverty.

poor socio-economic conditions in the western rural areas contributes to the deprivation of rural women. Due to poor infrastructures such as transportation and information technology, they are delayed in information exchanges (Yang et al. 2021). Therefore, they are more likely to join forces that lag behind the development of society.

The temporal results revealed that the poverty risk of rural women was decreased from 2010 to 2020, regardless of breadth, depth, or intensity. This is largely attributed to China's poverty alleviation policies and public services, which have eased the livelihood difficulties of rural women (Guo et al. 2022; Liu and Xu 2016). In particular, since China implemented the Targeted Poverty Alleviation Policy in 2013, the achievements of poverty alleviation have gradually become visible. This could be a reason why the MPI in 2012 was higher than the MPI in 2010 among rural women, but the MPI began to decline steadily from 2012 to 2020. Additionally, significant improvements in economic status, social welfare and living standards are helpful to reduce rural women's MPI. It should be noted that education, health and subjective wellbeing still occupied an important place in rural women's MPI in 2020. On the one hand, literacy is a major factor that influences the deprivation of opportunities and achievements (Xu et al. 2021). In the rapidly developing society, the mismatch between educational attainment and realistic expectation leads to life vulnerability of rural women. On the other hand, because of poverty alleviation policies, income is no longer the only problem that plagues people's lives. Rural women have the basis to pay attention to their own health and subjective wellbeing. Therefore, the importance of non-material indicators gradually increased in this research. Especially, group pressure and competitive conflicts are also prevalent in rural areas, so that rural women face new life threats (e.g., technology obsolescence and culture incompatibility), causing damage to their

mental health. This may be why the incidence of depression has increased over time.

## Conclusion

Based on the CFPS data from 2010 to 2020, this research used the A-F approach to portray the static and dynamic state of rural women's MP in China. The results found that rural women were more likely to be multidimensional poor in different subgroups. Ageing, no spouses and no confidence in the future exacerbated the risk of rural women's MP. And there were significant differences in the spatial and temporal distribution. On the one hand, rural women in the Western Region were at the highest risk of MP, followed by those in the Central Region, and the lowest risk in the Eastern Region. On the other hand, rural women's MPI had been decreased from 2010 to 2020. The deprivation rates in economic status, social welfare and living standards dropped significantly, meanwhile, the contribution ratios of education, health and subjective wellbeing showed an upward trend during this period. In terms of the above conclusions, this study has some implications for poverty alleviation of rural women.

Firstly, women, especially rural women, in this study are more vulnerable to MP than men, indicating that there are gender differences in poverty. Therefore, it suggests to adopt a gender perspective in the process of poverty reduction, and keep an eye on the individual needs of rural females. On the one hand, we advocate families and society to respect and treat women's labor efforts in life equally. Even housework is also women's contribution to the family (Arora and Rada 2017; Sen 1999a), which deserves to be understood and acknowledged. On the other hand, it should establish and improve women's rights protection mechanisms, such as education, marriage, employment, pension,

etc., to promote equality of resources and reduce the patriarchal preference. A “female-friendly” social environment provide support for the development of rural women to improve their confidence in life.

Secondly, the spatial difference results indicate that the causes of poverty are diverse, involving the geographical environment, social system and culture (Zhou and Liu 2022). Therefore, we should also adopt a pluralistic perspective to solve rural women’s MP. The differences in regional conditions and local customs need to be considered to formulate targeted poverty alleviation policies for rural women. For example, in view of the differences in rural women’s MP in the Eastern, Central and Western regions, it is recommended to increase direct assistance, including money, materials, etc., for rural women in high-risk areas to ensure their basic living needs. Then, environmental improvement projects in rural areas in the Central and Western regions should be promoted to stabilize the ecological environment while promoting infrastructure improvement (Liu et al. 2017; Zhu et al. 2022). The adaptation and growth needs of rural women should be taken into consideration when relocating for poverty alleviation, such as customs, social security, etc.. Provide them with a development platform in the new surroundings, and rural women will become more resilient to poverty.

Thirdly, the temporal dynamic results indicate that rural women’s poverty alleviation is a long process. Thus, this study recommended establishing a dynamic tracking system to adjust evaluation indicators based on annual statistical data. It will provide real-time references to improve the effectiveness of poverty governance. For example, it can appropriately increase the weight of education, health and subjective wellbeing dimensions, and refine their specific measurement indicators, so as to provide a basis for reducing the risk of rural women’s MP. In response to the results of poverty types, a prevention and monitoring mechanism of rural women’s MP should be established. We need to be wary of non-poor people falling into poverty in the future, and also pay attention to the ratio of chronic poor people and temporary poor people. This can provide evidence for optimizing poverty alleviation programs.

This research from an individual perspective revealed the breadth, depth and intensity of rural women’s MP, which provided support to deal with female impoverishment. However, there are still some limitations that need to be improved. First, the timeliness may be insufficient due to the secondary data. In the future, we should design and collect first-hand data to provide more direct and solid evidence. Second, the CFPS data are designed for China so that the results are country-specific. It can provide a theoretical reference but might not fully represent the situation of other countries. Therefore, international data are needed to achieve international conclusions and suggestions in the future. Third, although this research provides data support for the measurement of rural women’s MP, it is limited to fully expand the causal mechanism. In order to provide a more favorable complement, we should build a more comprehensive model to explore the causal logic in depth.

### Data availability

The raw data that support the findings of this study were originally collected by the Institute of Social Science Survey (ISSS) of Peking University, China. They can be publicly accessed via the CFPS website. An archive is available at <https://opendata.pku.edu.cn/dataset.xhtml?persistentId=doi:10.18170/DVN/45LCSO>. The datasets named “CFPS 2010/2012/2014/2018/2020 in STATA (Chinese)” were used during the current analysis. And the datasets generated are available from the corresponding author (s) on reasonable request.

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### Notes

- Source: United Nations, New York. The Sustainable Development Goals Report 2023. Retrieved from <https://unstats.un.org/sdgs/report/2023/>
- Source: The National Rural Revitalization Administration. Chinese Experience in Poverty Alleviation Among Women in The New Era (Chinese). Retrieved from [https://nrra.gov.cn/art/2020/12/30/art\\_624\\_186064.html](https://nrra.gov.cn/art/2020/12/30/art_624_186064.html)
- Source: State Council Information Office, China’s Practice of Human Poverty Reduction (Chinese). Retrieved from <http://www.scio.gov.cn/ztk/dtzt/44689/45216/index.htm>
- Source: OPHI. Global MPI Country Briefing 2023: China (East Asia and the Pacific). Retrieved from [https://ophi.org.uk/wp-content/uploads/CB\\_CHN\\_2023.pdf](https://ophi.org.uk/wp-content/uploads/CB_CHN_2023.pdf)
- Source: OPHI. National MPI Reports. Retrieved from <https://ophi.org.uk/publications/national-mpi-reports/>
- Gender inequality is measured by “the sex/poverty ratio” in this article. This is simply the ratio of the women’s rate (H, A, M0) to the men’s one; therefore, it is a relative measure of the status of women and men.
- Source: State Council. The Outline for Women’s Development in China (2021–2030) (Chinese). Retrieved from [https://www.gov.cn/zhengce/content/2021-09/27/content\\_5639412.htm](https://www.gov.cn/zhengce/content/2021-09/27/content_5639412.htm)
- Source: National Bureau of Statistics. Retrieved from <https://data.stats.gov.cn/easyquery.htm?cn=E0103>. The Eastern Region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, Hainan, 12 provinces, autonomous regions, municipalities. The Central Region includes Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, 9 provinces, autonomous regions. The Western Region includes Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Ningxia, Qinghai, Xinjiang, 9 provinces and autonomous regions.
- Source: National Bureau of Statistics. What is the poverty standard and poverty incidence rate (2020) (Chinese). Retrieved from [http://www.stats.gov.cn/zsk/snapshot?reference=cd54890348e2d3f37c9532b789f19a17&index=resource\\_data&qt=%E8%B4%AB%E5%9B%B0%E6%94%B6%E5%85%A5%E6%A0%87%E5%87%86&siteCode=tjzsk](http://www.stats.gov.cn/zsk/snapshot?reference=cd54890348e2d3f37c9532b789f19a17&index=resource_data&qt=%E8%B4%AB%E5%9B%B0%E6%94%B6%E5%85%A5%E6%A0%87%E5%87%86&siteCode=tjzsk)

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## Author contributions

NL contributed mainly to text writing, data analysis and revisions. MH contributed primarily to guidance, revisions and communications. Both authors discussed the results and contributed to the final manuscript.

## Competing interests

The authors declare no competing interests.

## Ethical Approval

This article does not contain any studies with human participants performed by any of the authors.

## Informed Consent

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## Additional information

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