Gender Differences in Multidimensional Poverty in Brazil: A Fuzzy Approach

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Abstract

This study aims to improve the measurement of multidimensional poverty for the purpose of analyzing gender differences while considering the limitations of household surveys. To effectively analyze gender disparities, it addresses three issues that are often overlooked in the literature: disregard for within-household inequalities in household-level indicators; disregard for ineligible populations in indicators that represent only a specific group; and disregard for intermediate deprivation situations in cutoff-based poverty estimations. Using data from the Brazilian Consumer Expenditure Survey 2017–2018, we create two indexes with indicators that are key aspects in gender and feminist analyses. Applying a fuzzy approach and the Alkire–Foster method, we estimate multidimensional poverty and gender differences from three perspectives: intrahousehold, interhousehold, and intracouple. We also calculate inequality among the poor and intracouple gender gaps proposing fuzzy versions for these analyses. The main findings suggest that women are disadvantaged in terms of work and time quality, economic security, and access to resources—all of which are crucial components of agency or degree of empowerment.

Keywords Gender differences · Multidimensional poverty · Fuzzy-set approach · Alkire–Foster method · Brazil · Latin America

1 Introduction

Economic analysis should be especially attentive to problems faced by women given that they tend to bear a disproportionate burden of development issues (Nussbaum, 2000). Multidimensional approaches to poverty measurement provide ways to account for the complexity of the phenomenon and its gendered nature. The literature on multidimensional poverty recognizes that focusing only on income or consumption expenditure is insufficient because people potentially have simultaneous deprivations (Alkire et al., 2015). This

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recognition is a significant advancement, but this literature often neglects aspects that are essential to estimate gender differences in multidimensional poverty.

For example, most studies on multidimensional poverty use households as the only unit of identification (Espinoza-Delgado & Klasen, 2018; Klasen & Lahoti, 2020). The problem is that many well-being elements are a characteristic of individuals (Deaton, 1997), and several inequalities are generated and experienced inside dwellings (Eek & Axmon, 2015; Griep et al., 2016; İlkkaracan & Memiş, 2021; Rodríguez, 2016). By only using household-level indicators, these studies define inequality within households as zero for all variables, as they set the same deprivation value among household members in each indicator. Moreover, Klasen and Lahoti (2020) show that studies defining household-level poverty thresholds from individual-level indicators create biased poverty estimations. Consequently, studies using exclusively household-level indicators cannot estimate gender differences within households and are potentially biased.

Another issue is understanding how to address ineligible populations from indicators that represent only a specific population group. For instance, employment-related indicators tend to include only working-aged people. In this case, studies usually classify children and the elderly in pension as missing units or non-deprived, potentially underestimating poverty outcomes. Another source of complexity that receives little attention from the literature is the potential vagueness[1] nature of indicators. Frequently, researchers treat poverty indicators as a rigid binary phenomenon (deprived or non-deprived), defining a specific cutoff to decide who is poor. This kind of approach neglects intermediate situations.

Given these problems in the literature, this paper aims to enhance the measurement of multidimensional poverty for the purpose of analyzing gender differences while considering the limitations of household surveys. The analysis focus on women's outcomes compared to men, but it also contemplates household headship, age, family composition, regions, ethnicity/color, and area type (urban/rural) in Brazil. Moreover, this study considers three different perspectives: results for the whole population (intrahousehold), household heads (interhousehold), and couples (intracouple). This paper applies the following three improvements to the problems discussed previously.

First, to avoid the problems of using only household-level indicators, we use individual-level indicators—when available—to build the multidimensional indexes. We propose two multidimensional poverty indexes. The first is the Standard Multidimensional Poverty Index (SMPI), which has similar dimensions to the Global Multidimensional Poverty Index (GMPI)[2] (OPHI & UNDP, 2019) but adapted for the Brazilian context and data availability. This index works as a benchmark by selecting indicators commonly used in the multidimensional poverty literature. The second is the Economic Autonomy Index (EAI), which aims to understand and compare the quality of employment and time of individuals, analyze their financial situation, and have a proxy for control and administration of resources.

The two proposed indexes use information that is commonly present in household budget surveys. Therefore, researchers can apply these indexes, at least in parts, in studies analyzing other countries. However, most household surveys lack individual data (Deaton,

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[1] As stated by Qizilbash (2006, p.10), studies usually classify vague indicators as having these three characteristics: (1) they allow borderline cases (e.g., a level of deprivation that one is not sure whether a person is poor or not); (2) they have no sharp borderline (e.g., no exact poverty line where it is clear that an individual bellow it is poor and above it is non-poor); and (3) they are susceptible to a Sorites paradox.

[2] The GMPI dimensions are Education, Health, and Living Standards. The indicators are nutrition, child mortality, years of schooling, school attendance, cooking fuel, sanitation, drinking water, electricity, housing, and assets.

1997), and that is why our indexes contain a mix of indicators at different levels. To mitigate the lack of individual data, especially for the SMPI, we also analyze multidimensional poverty among household heads. In the interhousehold perspective, individuals typically provide responses to all survey questions, enabling us to get a greater number of indicators at the individual level. However, it is important to view this analysis in conjunction with the other two perspectives. Because the two groups of household heads systematically differ from each other, the interhousehold perspective may introduce biases into the outcomes.

Second, to mitigate the problem of ineligible populations, we create individual composite indicators adapting the variables, when possible, to account for non-applicable populations. In this way, we can include different age groups in the same indicator to represent how they would be damaged when the eligible individuals in their household are deprived. For example, this paper considers children as deprived in employment- and financial-related indicators when every adult in their household is deprived in these indicators. Because children depend emotionally and economically on adults, the assumption is that children experience a negative effect from the adults' deprivation situation.

Third, to account for the vagueness nature of indicators when measuring multidimensional poverty, we use a fuzzy set approach, which treats poverty as a matter of degree instead of a binary phenomenon. The approach also has the advantage of presenting smaller standard errors, giving us more precise subgroup outcomes (Betti et al., 2012, 2018). The fuzzy set approach has gained increasing popularity in the construction of social indicators in different fields (see Betti and Lemmi, 2021). Cerioli and Zani (1990) were pioneers in applying the fuzzy set approach to measure poverty. Later, Cheli and Lemmi (1995) further developed the approach through the Totally Fuzzy and Relative (TFR) approach, and Betti et al. (2006) introduced the Integrated Fuzzy and Relative (IFR) approach. Other methodological contributions include Zedini and Belhadj's (2014) non-parametric method for unidimensional measures, Chakravarty's (2019) axiomatic approach for multidimensional poverty, Fattore's (2015) framework for ordinal attributes, and Handastya and Betti's (2023)4 double fuzzy-set approach recognizing that variables may belong to more than one dimension.[3] Specifically for labor-related indicators, Belhadj (2015) developed an employment measure using a fuzzy poverty indicator and minimum wage, and Cheli et al. (2021a) proposed a fuzzy measure for employment and unemployment.

Besides the fuzzy set, we also use the Alkire-Foster method (AF). Even though the AF is a cutoff-based approach, it has the advantage of providing intuitive measures and vast possibilities of decompositions, it also works as a benchmarking for setting the parameters of the fuzzy analysis, and gives complementary results from a distinct approach to measure poverty. The AF is an absolute measure, whereas the fuzzy is a relative one, so presenting results from both approaches also works as a robustness analysis. Therefore, this paper considers both approaches as complementary methodologies instead of contrasting ones.

This paper also calculates a "crisp" and a fuzzy version of inequality among the poor and intracouple gender gap. To measure the crisp inequality among the poor measure, we apply the method proposed by Alkire and Seth (2014). For the fuzzy version, we propose a measure that calculates the inequality of membership degrees, considering a new benchmark for the fuzzy membership function (i.e., the incidence of extreme multidimensional poverty instead of multidimensional poverty). As for the intracouple gender gap indexes, we apply the index proposed by Alkire et al. (2013) for the crisp measure and adapt it to

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[3] For more details on the evolution of the fuzzy-set approach and additional contributions, refer to Cheli et al. (2021b).

create a fuzzy version. The intention is to evaluate intracouple relative differences in more detail.

The recognition that the individual-level is the most appropriate unit of identification in multidimensional poverty analyses is not new (see Alkire & Santos, 2010; Deaton, 1997). One of the main reasons for the lack of individual-based studies is that household surveys usually focus on households (Alkire & Santos, 2010; Deaton, 1997). That is why most studies using individual-based indexes apply the analysis to specific subgroups such as occupied people (see Sehnbruch et al., 2020; and González et al., 2021), women (see Alkire et al., 2013; and Batana, 2013), children (see Alkire et al., 2019), and adults (see Burchi et al., 2021; and Vijaya et al., 2014). Klasen and Lahoti (2016) were the first to propose individual-based poverty analysis for the whole population. Their article shows that it is better to use a mix of household and individual-level indicators than only household-level ones, as the household-based index underestimates poverty differences between women and men in India.

Following Klasen and Lahoti (2016), other studies use multidimensional indexes mixing household and individual-level data (see Burchi et al., 2021; Correa, 2014; Espinoza-Delgado & Klasen, 2018; and Espinoza-Delgado & Silber, 2021). However, they do not consider other perspectives, such as interhousehold and intracouple. Moreover, there are also studies on gender inequalities that only rely on the sex of household heads. But they do not use individual-level indicators or employ multidimensional indexes, and some use household heads as a proxy for all women, which can bias the outcomes (see Bradshaw et al., 2017; Liu et al., 2017; Montoya & Teixeira, 2017).

Considering these gaps in the literature, the contributions of this paper are the following. Empirically, it offers a comprehensive analysis combining intrahousehold, interhousehold, and intracouple perspectives and evaluating multidimensional poverty, inequality among the poor, and gender gaps considering several subgroups and two approaches. As far as we are aware, this is the first paper to focus on individual-based multidimensional poverty for the whole population in Brazil and the first paper to combine the three perspectives. Methodologically, this article creates the EAI, which uses indicators that are key aspects in gender and feminist analyses, and proposes a fuzzy version of the measures of inequality among the poor and intracouple gender gap.

The structure of this paper is the following. Section 2 details the data and methodologies. Section 3 presents and details the indexes, dimensions, and indicators. Section 4 shows the results, and Sect. 5 concludes.

2 Data and Methodology

This section begins by describing the dataset and subsequently explain the measures we employ and propose. We also highlight the advantages of each poverty measures and their purpose. As it will become clearer, in conjunction, the main value added by these indexes is to shed light in different aspects and magnitudes of gender differences.in multidimensional poverty.

2.1 The Brazilian Household Budget Survey

The Brazilian case is a compelling example not just due to the country's importance, but also because of the availability of a rich dataset. This availability allows us to illustrate the

improvements we propose by dealing with different types of variables and creating comprehensive indexes.

In this paper, we use the microdata from the Brazilian Consumer Expenditure Survey (POF) 2017–18, collected and processed by the Brazilian Institute of Geography and Statistics (IBGE). The choice of this particular period is because it is the most recent round of the POF, which is a comprehensive and high-quality survey that provides detailed information necessary for building multidimensional poverty indexes. This survey is mainly focused on households, so the information that we get is a mix of household-level and individual-level data (see Sect. 3 for details of the level of each indicator).

The sample size is 69,660 households, and the data contains information at the levels of nation, major regions, states, state capitals, metropolitan regions (excluding the capital), other parts of the states (excluding the metropolitan regions and state capital), and at urban and rural areas. Following IBGE (2020b), we excluded from the data individuals classified in the households as domestic workers and domestic workers' relatives, accounting for 62 observations deleted. Because this paper relies on household heads as one of the analysis' perspectives, we now describe its definition in the Brazilian household budget survey. The POF considers as household head people that hold, in order of importance, at least one of these criteria: (1) the responsible for paying the rent; or (2) the responsible for paying the installment for the house purchase (installment contract owned by one of the residents); or (3) the responsible for paying the housing expenses (e.g., condominium fee, property tax, household services and fees, and others) (IBGE, 2017). If no household member satisfies any of these three conditions, the household members indicate the household head. In addition, if two members simultaneously satisfy one of the three criteria, the survey considers as household head the oldest one between them.

From this household head definition, we can observe that household heads are responsible for important payments or are the reference person in their home. Therefore, interpreting cautiously, we can consider household headship as an indication of people's agency or empowerment—and that is another reason to consider the interhousehold perspective in the poverty analysis.

2.2 Multidimensional Poverty Measures

2.2.1 The Alkire–Foster Method

The AF methodology is a counting approach to measure multidimensional poverty proposed by Alkire and Foster (2011). One of the main advantages of the AF method is that it is simple and intuitive. In this method, the first element of multidimensional poverty is the incidence, or headcount ratio (H), which is the percentage of people identified as multidimensionally poor:

$$H = \frac{\sum_{i=1}^{n} \rho_k(x_i;z)}{n} = \frac{q}{n}, \tag{1}$$

where x_i is the vector of achievements of individual i, z is the vector of deprivation cutoffs, q is the number of multidimensionally poor, and n is the number of the total population. This approach identifies as poor those with a deprivation score, c_i, higher than the poverty cutoff, k. That is, if $c_i(k) \geq k$, then $\rho_k(x_i;z) = 1$; if $c_i(k) < k$, then $\rho_k(x_i;z) = 0$.

The second element of the measure, the poverty intensity (A), is the average deprivation score among poor individuals:

$$A = \frac{\sum_{i=1}^{q} c_i(k)}{q}, \tag{2}$$

where $c_i(k)$ is the censored deprivation score of individual i, replacing with zero the deprivation scores of non-poor individuals. Formally, when $c_i(k) \geq k$, $c_i(k) = c_i$, and $c_i(k) < k$, $c_i(k) = 0$, otherwise.

Finally, the adjusted headcount ratio (M_0), or multidimensional poverty index (MPI), is the product of the headcount ratio and the intensity:

$$M_0 = H \times A \tag{3}$$

Following the standard definition by OPHI and UNDP (2019) for the Global MPI, we set the multidimensional poverty cutoff, k, as one-third of the weighted deprivations and the dimensions as having equal weights. Table 1 presents the resulting weights for each variable.

To estimate poverty using this approach, scholars should avoid mixing different types of indicators (binary, discrete, continuous) in the same index (Alkire & Foster, 2011). Hence, according to a defined cutoff, we transform discrete, ratio, and count variables into binary variables (deprived or non-deprived).

This paper focuses on the outcomes of the incidence (H) because it is the benchmark measure for calculating the membership degrees of the fuzzy approach.

2.2.2 The Fuzzy Set Approach

The fuzzy set approach to measuring multidimensional poverty accounts for the vagueness nature of the indicators. One of the main advantages of this method is that instead of treating the deprivations as dichotomic measures (0 or 1), it allows individuals to belong to varying degrees in the "fuzzy set" of being poor/deprived and, therefore, account for intermediate situations.

To estimate the fuzzy multidimensional poverty, we use the Integrated Fuzzy and Relative (IFR) approach proposed by Betti et al. (2006). This approach determines the membership degrees according to the individual's position in the indicators' scores distribution (see Betti & Lemmi, 2021). The membership function for multidimensional analysis, as defined by Betti et al. (2015), is the following:

$$m_i = \left[1 - F(X_i)\right]^{\alpha-1} \left[1 - L(X_i)\right] = \left(\frac{\sum_\gamma w_\gamma |X_\gamma\rangle X_i}{\sum_\gamma w_\gamma |X_\gamma\rangle X_1}\right)^{\alpha-1} \left(\frac{\sum_\gamma w_\gamma X_\gamma |X_\gamma\rangle X_i}{\sum_\gamma w_\gamma X_\gamma |X_\gamma\rangle X_1}\right) \tag{4}$$

where F and L are, respectively, the cumulative distribution function and the Lorenz curve for the variable X and individual i, X is the monetary or non-monetary deprivation indicator, ω_γ is the individual sample weight ranked by γ, and α is a parameter. The calculation of α is such that the mean of the fuzzy indicator is equal to the incidence (H) estimated in the AF method.

In the fuzzy approach, we use the variables in their discrete, count, or ratio version when available because we can grasp more information from the data to calculate the membership degrees. For some variables, we can only have binary information (Sect. 3.3 details the type of each indicator), but to mix different types of data in the same index is not a problem in this approach, as they are transformed to allow meaningful comparisons (see Betti et al., 2015).

Table 1 Multidimensional poverty indexes, dimensions, indicators, and cutoffs

Dimension	Indicator	In the AF method, the individuals are deprived if…	Level	Standard Weight*	P–C Weight**
STANDARD MPI					
Education	Schooling achievement	(Preschool children) they are not attending daycare, preschool, or primary school, and the head of their household has not completed lower secondary school. When infants are less than three years, the measure classifies them as not deprived. (Children and Adolescents) they are not on course to complete lower secondary school by the age of 17. (Adults and Elderly) they have not completed lower secondary school.	Individual	0.166	0.167
	Education subjective	the head of their household considers the family's standard of living in relation to education as bad.	Household	0.166	0.167
Health and Food Security	Share of expenditure on food	in their household, food represents 75% or more of the total consumption expenditure.	Household	0.111	0.120
	Food security index	their household have light food insecurity or more, according to the Brazilian Scale of Food Insecurity (EBIA).	Household	0.111	0.104
	Health subjective	the head of their household considers the family's standard of living in relation to health as bad.	Household	0.111	0.110

Table 1 (continued)

Dimension	Indicator	In the AF method, the individuals are deprived if…	Level	Standard Weight*	P–C Weight**
Living Standards	Housing	in their household, the housing materials for at least one of the floor, roof, and walls are inadequate.	Household	0.041	0.037
	People-per-bedroom	in their household, there are three or more residents per permanent bedroom.	Household	0.041	0.037
	Drinking water	in their household, the water frequency is not daily; or there is no indoor plumbed water; or the water does not come from the public distribution system.	Household	0.041	0.033
	Sanitation	in their household, sanitation is not improved; or it is shared with other households; or the sewage disposal is not connected to the public system.	Household	0.041	0.045
	Electricity	their household has no access to electricity.	Household	0.041	0.045
	Cooking fuel	in their household, the cooking fuel is wood, oil, kerosene, or another liquid fuel.	Household	0.041	0.041
	Assets	their household does not own a car or truck and does not own more than one of these assets: computer, radio, TV refrigerator, bicycle, or motorbike.[1]	Household	0.041	0.046
	Housing subjective	the head of their household considers the family's standard of living in relation to housing as bad.	Household	0.041	0.049

Table 1 (continued)

Dimension	Indicator	In the AF method, the individuals are deprived if…	Level	Standard Weight*	P–C Weight**
ECONOMIC AUTONOMY INDEX					
Quality of Employment	Informality	(Children and Adolescents) they are working in illegal conditions, or all adults in their household are deprived in this indicator. (Adults) they have an informal job. (Elderly) they have an informal job or have no income (except conditional cash benefits).	Individual	0.125	0.099
	Deprivation on employment	(Children and Adolescents) they are working in illegal conditions, or all adults in their household are deprived in this indicator. (Adults) they do not have a job and are not studying, or are employed without pay and are not studying. (Elderly) they have no income (except conditional cash benefits).	Individual	0.125	0.167
	Commuting time	(Children and Adolescents) the average commuting time of the adults in their household is larger than one hour. (Adults and Elderly) they spend more than one hour to arrive at their workplace from home.	Individual	0.125	0.134
	Leisure subjective	the head of their household considers the family's standard of living in relation to leisure as bad.	Household	0.125	0.100

Table 1 (continued)

Dimension	Indicator	In the AF method, the individuals are deprived if…	Level	Standard Weight*	P–C Weight**
Resources	Dependency ratio	in their household, the proportion of children and elderly without an income in relation to adults is bigger than two.[2]	Household	0.083	0.080
	Housing tenure	they are renting their accommodation under a verbal rental contract, or they are living in a ceded house or occupied house, or the rent payment refers to the household in conjunction with a non-residential unit (store, workshop, and others).	Household	0.083	0.108
	Financial access	(Children and Adolescents) all adults and elderly in their household are deprived in this indicator. (Adults and Elderly) they have no access to financial products (bank account, check pay, credit card, or saving account).	Individual	0.083	0.089
	Private insurance	they have no access to private health insurance.	Individual	0.083	0.076
	Payment difficulties	in their household, due to financial difficulties, they delayed one of the following payments more than two times in the last 12 months: rent, house installments, bills, or goods and services.	Household	0.083	0.074
	Financial subjective	the head of their household considers that the family's income allows them to live until the end of the month with difficulty or a lot of difficulty.	Household	0.083	0.073

*Dimensions have equal weights, and indicators within the same dimension have equal weights. **Prevalence-correlation weights, based on the dispersion and correlation among the indicators (see Sect. 2.2.2). 1. Cars and trucks have double weight within the indicator. 2. If the household is composed only of elderly without an income with or without children/adolescents, we multiply the number of residents by two. In this way, these individuals will always be deprived in the AF method and have a double weight in the fuzzy approach

Regarding the indicator's weights, we estimate them using the prevalence-correlation principle as proposed by Betti and Verma (2008) to avoid arbitrariness in choices. The intuition is to account for the dispersion of the indicators by considering critical the deprivations that affect only a small share of the population and to avoid redundancy of variables that are highly correlated with others. Moreover, because the analysis focuses only on one year, it does not violate poverty indices properties that may occur in data-driven weighting methods for multiple years.[4]

2.3 Measures of Inequality Among the Poor

Analyzing inequality among the poor is important because a decrease in inequality within this group indicates a reduction that has also benefited individuals living in extreme poverty. To calculate inequality among the poor, we use a cutoff-based measure and a fuzzy measure. For the first, we use a positive multiple of variance as proposed by Alkire and Seth (2014). This cutoff-based inequality measure is the following:

$$I_q = \frac{3}{q} \sum_{i=1}^{q} \left[c_i(k) - A \right]^2,$$

(5)

where q is the number of multidimensionally poor individuals, $c_i(k)$ is the censored deprivation score of the individual i, and A the intensity of poverty.

As for the second measure, we propose a fuzzy indicator also using the variance. To build this measure, we set a new α in Eq. 4 such that the mean of the fuzzy indicator is equal to the incidence of extreme poverty (the threshold is half of the weighted deprivations instead of one-third). This means that we are increasing the parameter α giving more weight to the lowest part of the distribution. After estimating the fuzzy extreme poverty indicator, we calculate the inequality of extreme poverty membership degrees as follows:

$$I_{fz} = \frac{1}{n} \sum_{i=1}^{n} \left[m_i' - \mu\left(m'\right) \right]^2,$$

(6)

where n is the number of the total population, m_i' is the extreme poverty membership degree of the individual i, and $\mu(m')$ is the average value of the extreme poverty membership degree. Because our measure gives more weight to the poorest, inequality will decrease more when improvements in the degree of poverty come from the bottom part of the distribution instead of those from the top.

2.4 Intracouple Gender Gap Indexes

To explore the intrahousehold analysis further, we use two measures. The first is the Gender Gap Index (GGI), a variation of the Gender Parity Index by Alkire et al. (2013) to measure relative intracouple inequality between the primary female and male in households with couples as primary members. For this index, following Alkire et al. (2013), when the individual deprivation score, c_i, is lower than or equal to the cutoff k, the $c_i'(k)$ replaces this value with the value of k. Formally, if $c_i'(k) > k$, $c_i'(k) = c_i$, but

when $c_i\prime(k) \leq k$, $c_i\prime(k) = k = 0.333$. This censoring intends to eliminate the influence of decreases in the deprivation scores of men that are not multidimensionally poor. This index classifies the households as lacking gender parity when the female is multidimensionally poor and her new censored deprivation score, $c_i\prime(k)$, is higher than the one of her partner.

The GGI measure calculation is the following:

$$GGI = H_{GGI} \times I_{GGI}, \tag{7}$$

where H_{GGI} is the percentage of women living in households with no gender parity, measured as the number of households classified as *lacking gender parity*, h, divided by the total of households with primary couples in their composition, z. The H_{GGI} computation is the following:

$$H_{GGI} = \frac{h}{z}. \tag{8}$$

And I_{GGI} is the average percentage gap between the censored deprivations of the women and men in a household in which there is no gender parity. The I_{GGI} calculation is the following:

$$I_{GGI} = \frac{1}{h} \sum_{j=1}^{h} \frac{c_j\prime(k)^M - c_j\prime(k)^W}{1 - c_j\prime(k)^M}, \tag{9}$$

where $c_j\prime(k)^W$ and $c_j\prime(k)^M$ are, respectively, the new censored deprivation scores of the primary female and the primary male (when they are partners) in the household j.

For the second measure, we propose the Fuzzy Gender Gap Index (FzGGI), which considers a household as having *disadvantaged women* when the poverty membership degree, m_i, of the primary male is lower than the primary female. For this index, the computation of the percentage of disadvantaged women is the following:

$$H_{FzGGI} = \frac{h^{fz}}{z}, \tag{10}$$

where h^{fz} is the number of households with disadvantaged women. The calculation of the average percentage gap between membership degrees of women and men in households with disadvantaged women (I_{FzGGI}) is the following:

$$I_{FzGGI} = \frac{1}{h^{fz}} \sum_{j=1}^{h^{fz}} \frac{m_j^{fzM} - m_j^{fzW}}{1 - m_j^{fzM}}, \tag{11}$$

where m_j^{fzW} and m_j^{fzM} are, respectively, the poverty membership degree of the primary female and the primary male (when they are partners) in the household j.

Finally, the calculation of FzGGI is the product of the previous two measures:

$$FzGGI = H_{FzGGI} \times I_{FzGGI}. \tag{12}$$

Because the definitions of households lacking gender parity and disadvantaged women are different, the GGI and the FzGGI results are not comparable. The GGI restricts the analysis for multidimensionally poor women, while the FzGGI includes all the households with couples as primary members. The FzGGI's perspective is also relevant because intra-couple gaps and inequalities are present in non-poor households as well.

3 Indexes, Dimensions, and Indicators

This section details the indicators and supports them using the theoretical and empirical literature. The focus is on the dimensions of the EAI, as the dimensions of the SMPI are extensively discussed in the literature (see Alkire & Santos, 2010; and Anand & Sen, 1997).

Table 1 presents the structure of the two indexes, the AF method's cutoffs,[5] and the indicators' weights. Each dimension includes a subjective indicator, which accounts for the self-understanding of the household heads about their household's situation in that dimension. The subjective indicators work as complements to the other indicators.

3.1 The Standard Multidimensional Poverty Index

3.1.1 Education

This paper measures the dimension of Education with two indicators: *School achievement* and *Education subjective*. The first is an individual-level indicator based on a similar measure proposed by Espinoza-Delgado and Klasen (2018). For the elderly (greater than or equal to 60 years old) or adults (between 16 and 59 years old), this measure counts the number of completed years of education in relation to the conclusion of the elementary school. For instance, if a person's education level is elementary school, the indicator is 0; if a person has three years of additional study after the completion of elementary school, the measure is 3; and if a person has three years left to complete the elementary school, the measure is −3. The same logic applies to adolescents (between 12 and 15 years) and children (between 4 and 11 years old), but, in these cases, the indicator calculates if the individual is on track to conclude the elementary school, giving a buffer of two years to account for the many reasons a student can be in delay.

The second indicator, *Education subjective,* illustrates the perception of household heads of the family's standard of living regarding education, ranging from good, satisfactory, and bad.

3.1.2 Health and Food Security

For this dimension, we propose three indicators: *Share of expenditure on food, Food Security Index*, and *Health subjective*. Ideally, health and food consumption data should be at the individual-level. However, health is one of the most difficult dimensions to measure, as most surveys do not offer data for all the household members (Alkire & Santos, 2010). Therefore, because it is not possible to calculate the indicators at the individual level for the whole population, the three indicators are on the household level.

The first indicator, *Share of expenditure of food,* is the percentage of the household consumption expenditure on food products. The *World Food Programme* (WFP) and others use this indicator to assess food insecurity and identify families vulnerable to shocks affecting food prices (see Lele et al., 2016; Rose, 2012). As for the second indicator, *Food Security Index,* the IBGE calculates it following the Brazilian Household Food Insecurity Measure Scale (EBIA). The calculation uses psychological factors (e.g., worry that the food will run out), food quality, food quantity available for adults and children, and hunger (e.g., when

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[5] Some of the indicators and cutoffs are the same as in Tavares and Betti (2021).

someone does not eat all they long because of lack of money) (see IBGE, 2020a). The resulting scale is the following: food security, light food insecurity, moderate food insecurity, and severe food insecurity. Finally, the third indicator, *Health subjective,* accounts for the household heads' perception on the standard of living in terms of health in their home (good, satisfactory, and bad).

3.1.3 Living Standards

In this paper, eight indicators represent the Living Standards dimension: *Housing, People-per-bedroom, Drinking water*, *Sanitation*, *Electricity, Assets*, *Cooking Fuel,* and *Housing subjective*. In combination, these indicators stand for acute poverty. Some of them are related to health and affect mostly women, as the indicators of drinking water, sanitation, and cooking fuel (Alkire & Santos, 2010).

Building individual-based indicators for the living standards dimension is both empirically and conceptually tricky for two main reasons (Vijaya et al., 2014). First, there is no individual-level data in most surveys. Second, we cannot know whether individuals within a household use the goods equally or if someone has control over them. Therefore, following other studies (Burchi et al., 2021; Espinosa-Delgado & Klasen, 2018; Vijaya et al., 2014), we built these variables at the household level assuming that they are semi-public goods with equal access among everyone within the household.

Regarding the indicators in this paper, *Housing* accounts for the material used in the roof, walls, and floor. *People-per-bedroom* measures the number of people per permanent bedroom in the household. *Drinking water* considers the weekly frequency of water supply, the presence or absence of plumbed running water inside the household, and the kind of water source. *Sanitation* evaluates the number of indoor bathrooms with shower and toilet, the existence of at least one private bathroom (not shared with other households), and the kind of sewage disposal available in the household. *Electricity* analyses whether the household has access to electricity and the weekly frequency of this access. *Assets* evaluates if the households have the following items: computer, radio, TV refrigerator, bicycle, motorbike, and car or truck. *Cooking Fuel* examines the kind of cooking fuel used in the household. Finally, *Housing subjective* analyzes the perception of the household heads on living standards regarding housing in their home (good, satisfactory, or bad).

3.2 The Economic Autonomy Index

3.2.1 Quality of Employment

The dimension "Quality of Employment" works as a proxy measure of work and time quality, which are key aspects in gender and feminist economics analyses (see Berik & Kongar, 2021). This dimension includes four indicators: *Informality*, *Deprivation on employment, Commuting time,* and *Leisure subjective.*

The first indicator, *Informality,* is an important indicator in the Global South as it represents the situation of a big share of their workers. The consequence of high informality is that a large part of the population remains without access to the social security system. Moreover, informal workers face additional challenges because they tend to be not unionized, lack awareness of their rights, have dispersed activities, have irregular earnings, and get devaluated jobs (Kabeer, 2021). The indicator in this paper is an individual-level measure that select some work categories considering the workers' accessibility to social

security to have a proxy for informal occupation, as suggested by the IBGE (2020b). The selected categories are the following: auxiliary family workers; private-sector employees and domestic workers without a formal contract; and employers and self-employed workers who do not contribute to social security.

Regarding the treatment of ineligible subgroups, *Informality* considers children and adolescents as deprived if they work in illegal conditions[6] or if every adult in their household has an informal job. Elderlies are deprived when they have an informal job or no income because these two situations indicate that they have no access to the social security system and probably did not have this access during most of their career.

The second indicator, *Deprivation on employment,* is a complementary measure to informality as it includes other situations in which people may be vulnerable. This indicator is at the individual level, and it defines adults as deprived if they do not have a job and are not studying or if they are employed without pay and are not studying. Children and adolescents are deprived when working in illegal conditions (the same as the *Informality* indicator) or when everyone in their household is deprived on employment. Elderlies are deprived when they have no source of income, which means that they are deprived on social protection. A limitation of this indicator is that the POF does not cover unpaid domestic work. This measure partially captures unpaid domestic work through the non-working status in the dataset, but it does not capture people working a "second shift," meaning people who have a paid job and are also responsible for unpaid domestic work. Therefore, this indicator underestimates the deprivations of women because they are usually responsible for unpaid domestic work in Brazil (Barbosa, 2019; Lavinas et al., 2016).

The third indicator, *Commuting time,* is an individual-level indicator that accounts for the total time to arrive at the main job from home. This variable matters because it exposes and represents the gender inequalities in the labor market, the access to transportation, the division of domestic responsibilities at home, and the self-identity (Hanson & Johnston, 1985; Pereira & Schwanen, 2015). Moreover, long commute time is associate with poverty (especially in metropolitan areas), as poor people tend to be more vulnerable to transport disadvantages (Lucas, 2012; Pereira & Schwanen, 2015). For children and adolescents, the measure is the average commuting time of the adults in their households. A limitation of this measure is that the survey only gives information on the commuting time of the main job, ignoring people working in multiple jobs.

The fourth indicator, *Leisure subjective,* shows the household head's perception of the family's standard of living regarding leisure (good, satisfactory, or bad). According to Barbosa (2019), men have more leisure time than women in Brazil. Therefore, to see how the subjective measure differs between women and men is important, as it can reflect disparities in the time available for leisure.

In this dimension, the only indicator that is not at the individual level is the *Leisure subjective,* as only the household heads have answered it in the survey. Moreover, the treatment of ineligible population for the indicators *Informality* and *Commuting time* does not include adults who do not work. In these cases, we treat them as non-deprived.

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[6] According to law number 10.097 of December 2000, adolescents between 14 and 16 years old are allowed to work as an apprentice, not exceeding six hours a day (eight hours if they have finished elementary school). Moreover, adolescents that have not finished elementary school must attend school.

3.2.2 Resources

This dimension shows the economic situation of households and individuals, and the access to financial products and private health insurance. Therefore, the indicators can also be interpreted as aspects of agency or degree of empowerment (see Alkire, 2007; and Mishra & Tripathi, 2011).

The dimension comprises six indicators: *Dependency ratio, Housing tenure, Financial access, Private insurance, Payment difficulties, and Financial subjective.* The first indicator, *Dependency ratio*, intends to capture the economic vulnerability of households that rely on few household members to sustain a large family. This indicator measures the household proportion of children, adolescents, and elderly with no income with respect to adults. *Dependency ratio* is at the household level, but for the characteristics of the indicator, we cannot have an individual-based version.

The second indicator, *Housing tenure,* accounts for the arrangements under which the household occupies the accommodation (own home, rented, ceded, or occupied). The third indicator, *Financial access,* counts the number of different financial products that the individual has access to. For children and adolescents, this measure is the total of financial product types in their household. These two indicators are important because they are related to forms of agency (Kabeer, 2021). *Housing tenure* can reflect the extent to which the person has control over the property and social vulnerability due to informal arrangements and informal settlement. *Financial access* is a proxy of control over income, which is a key determinant of whether a person can exercise choices and benefit from his/her efforts (Alkire et al., 2013).

The fourth indicator, *Private insurance*, shows if the person has private health insurance or not. This measure also reflects inequalities in access to resources because having private insurance in Brazil depends on accessibility, ability to afford costs, and whether the job offers private insurance as a benefit. Of the previous three indicators we presented, only *Housing tenure* is at the household level because it is a classification of the property ownership status.

The fifth indicator, *Payment difficulties*, calculates the number of payment difficulties a household had for one year due to financial difficulties. The sixth indicator, *Financial subjective*, considers the household heads' assessments about the difficulty to live until the end of the month with the family's income. The answers options are very easy, easy, some facility, some difficulty, difficult, very difficult. These two indicators are complementary, showing the economic vulnerability of households. Both indicators are at the household level because there is no data available at the individual level.

3.3 Descriptive Statistics

Table 2 presents the types of data and score range for the indicators of the two indexes. As explained previously, we transform the discrete, count, and ratio indicators into binary variables for the AF method, while for the fuzzy approach, we use the indicators as discrete, ratio, or count when possible. In the binary indicators, zero means deprived, and one non-deprived. When the indicator is discrete or ratio, it ranges from no deprivation to complete deprivation. For count indicators like schooling achievement, assets, and financial access, they range from complete deprivation to no deprivation, except for payment difficulties, which ranges inversely.

Table 2 Data type and score range

Indicators	Data type	Min	Max
Standard MPI			
Schooling achievement	Count/Cardinal	−12	12
Education subjective	Discrete/Ordinal	1	3
Share of expenditure on food	Ratio/Cardinal	0	0.90
Food security index	Discrete/Cardinal	1	4
Health subjective	Discrete/Ordinal	1	3
Housing	Discrete/Ordinal	0	9
People-per-bedroom	Ratio/Cardinal	0.3	13
Drinking water	Discrete/Ordinal	0	6
Sanitation	Discrete/Ordinal	0	4
Electricity	Discrete/Ordinal	0	4
Cooking fuel	Discrete/Ordinal	0	2
Assets	Count/Cardinal	0	27
Housing subjective	Discrete/Ordinal	1	3
Economic autonomy index			
Informality	Binary/Cardinal	0	1
Deprivation on employment	Binary/Cardinal	0	1
Commuting time	Discrete/Ordinal	0	4
Leisure subjective	Discrete/Ordinal	1	3
Dependency ratio	Ratio/Cardinal	0	6
Housing tenure	Discrete/Ordinal	1	6
Financial access	Count/Cardinal	0	4
Private insurance	Binary/Cardinal	0	1
Payment difficulties	Count/Cardinal	0	3
Financial subjective	Discrete/Ordinal	0	5

Because of the novelty of the EAI, we present the pairwise correlations among all indicators to understand their relations (Fig. 1). The figure shows that the SMPI indicators (from 1 to 13) correlate positively, except *Schooling achievement* and *Assets* that have a positive correlation only with each other. As for the SMPI's indicators relationship with the EAI indicators (from 14 to 23), most have a negative but weak correlation, but a positive correlation with *Schooling achievement* and *Assets*. *Financial access* and *Private insurance* show relatively stronger negative correlations, especially with the food security index (the bigger it is, the worst is food security).

Moreover, *Payment difficulties* and *Financial subjective* also have a relatively stronger positive correlation with *Food security index* than other indicators. These results suggest that a bad financial situation is related to food insecurity. The correlations of *Financial subjective* also reveal that people with fewer assets, financial access, private insurance, and more payment difficulties tend to classify their financial situation negatively. Another interesting outcome is the relations among the subjective indicators: they are all positively correlated, meaning that a person is inclined to have similar perceptions in all the subjective indicators.
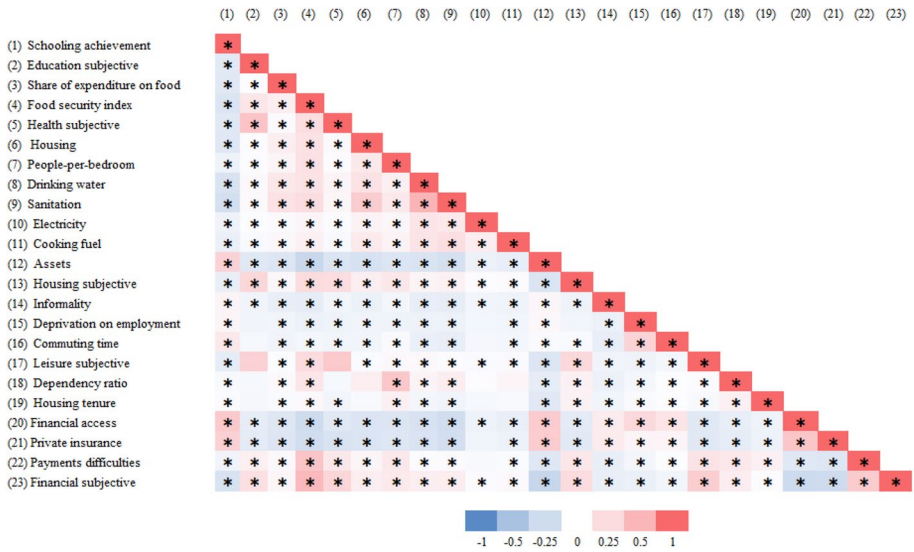
Fig. 1 Pearson correlation matrix of the indicators. *Notes: Significance level:* ***** *p < 0.01. For indicators 1, 12, 20, and 21, the larger they are, the less deprived an individual is. For the remaining indicators, the larger they are, the more deprived a person is*

4 Results

4.1 Estimations for the Whole Population: Intrahousehold Perspective

4.1.1 Multidimensional Poverty

In this subsection, we present the results of the multidimensional poverty indexes. Table 3[7] presents the results of the SMPI by gender for the incidence and fuzzy degrees of poverty, including outcomes for subgroups. The fuzzy results range between 0 and 100, with 0 representing the minimum poverty degree, and 100 the maximum. For this index, we can observe that multidimensional poverty appears not to be feminized because men have larger poverty outcomes than women for most subgroups and the two methods. In total, men are between 2% and 7% poorer than women.

However, individuals living in female-headed households are considerably worse off than those in male-headed households (although the female-male differences are smaller). Moreover, the results for single women and women living in households with no couples as primary members (i.e., adults without children and adults with children[8]) are unclear because each method produces a different result, or the outcomes are not statistically significant. The categories with the largest relative differences are Single without children, Couple with children, and Male-headed for the incidence; and Single with children, Couple without children, and Male-headed for the fuzzy results.

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[7] In this section, the outcomes of the category "Undeclared" in the subgroup Color/Ethnicity do not receive any comments, as the IBGE does not details when a person is classified as undeclared.

[8] In this section, "children" include both children and adolescents.

Table 4 shows the multidimensional poverty results for the EAI. Compared to the SMPI's results, the estimations reveal a different scenario, as multidimensional poverty is higher among women in most subgroups. According to the total results, women are between 5% and 7% multidimensionally poorer than men. Interestingly, women are in a better situation than men in female-headed households, and, in the fuzzy results, women are less multidimensionally poor in female-headed houses than in male-headed houses. Considering both methods, the categories that women are in most relative disadvantage with respect to men of the same group are Asian, Elderly, Elderly(ies), and Male-headed.

4.1.2 Inequality Among the Poor

We now present the inequality among the multidimensionally poor for both the SMPI and EAI. Table 5 shows the SMPI outcomes by subgroup. For this index, most categories reveal that inequality among the poor is higher for men with respect to women. In total, the inequality among multidimensionally poor, I_q, is 5% higher for men. The Indigenous population, Adults without children, and Single with children are the categories with the largest relative differences disfavoring men.

Regarding the fuzzy inequality estimations, I_{fz}, the outcomes are similar to those of the I_q, as men present higher inequality in most subgroups. The total fuzzy inequality is 6% larger for men with respect to women. The categories with the highest gender relative disparities are Indigenous (disfavoring women), Asian (disfavoring men), and South (disfavoring women).

Table 6 shows the results of the EAI by subgroups. The outcomes reveal that inequality among the poor is higher among women in most subgroups, although the differences are statistically significant only in three categories. The total Iq for women is 2% larger with respect to men. The largest relative gender differences in inequality are among Indigenous (disfavoring men), Asian (disfavoring men), and Center-west (disfavoring women).

For the fuzzy inequality results, in most subgroups, women are at a disadvantage. This time the disparities are more pronounced, and most differences are statistically significant. According to the total result, inequality is 20% larger for women. The relative differences in inequality are largest among Male headed, Elderly, and Elderly(ies), all of them with women at a disadvantage.

4.2 Estimations for Household Heads: Interhousehold Perspective

In this subsection, the focus is on household heads, providing an individual-based interhousehold perspective. As discussed in previous sections, restricting the data to household heads allows us to estimate more indicators at the individual level, but this perspective is not a proxy for all women. Therefore, the results here should be interpreted with caution due to potential biases of this analysis, as households headed by women tend to be associated with higher level of income poverty (Bradshaw et al., 2019).

In line with this association, different from the whole population perspective, the outcomes for the interhousehold perspective show that women are multidimensionally poorer with respect to men in most subgroups in both the SMPI and EAI. The SMPI outcomes (Table 7) show that, in total, female heads are between 10% and 15% multidimensionally poorer than male heads. For both approaches (H and Fuzzy), Indigenous, Asian, South, and Adults with children appear among the categories with the largest relative differences disfavoring women.

Table 3 Multidimensional poverty estimations and gender differences for the Standard MPI by subgroup

Variables	Standard MPI					Fuzzy				
	H (%)			Differences					Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Total	18.03	18.75	17.35	−1.40***	0.93	18.03	18.25	17.82	−0.44***	0.98
Household headship										
Male-headed	16.66	17.69	15.44	−2.25***	0.87	16.70	17.15	16.17	−0.97***	0.94
Female-headed	20.07	20.88	19.52	−1.36***	0.94	20.01	20.48	19.69	−0.79***	0.96
Age groups										
Child	12.21	12.88	11.49	−1.39***	0.89	18.21	18.54	17.87	−0.67*	0.96
Adult	18.27	19.41	17.21	−2.19***	0.89	17.04	17.35	16.75	−0.6***	0.97
Elderly	25.41	25.70	25.18	−0.52	0.98	21.81	21.81	21.81	0.00	1.00
Family composition										
Single without children[1]	17.62	18.93	15.80	−3.13**	0.83	17.86	18.24	17.34	−0.90	0.95
Single with children[1]	15.89	15.29	16.22	0.93	1.06	20.00	21.22	19.33	−1.88*	0.91
Couple without children[2]	14.69	15.59	13.71	−1.88***	0.88	14.91	15.43	14.34	−1.09***	0.93
Couple with children[2]	16.66	17.78	15.51	−2.27***	0.87	16.85	17.23	16.45	−0.78***	0.95
Adults without children[3]	15.85	15.62	16.04	0.42	1.03	17.40	17.16	17.59	0.43	1.03
Adults with children[3]	22.08	22.07	22.08	0.02	1.00	22.38	21.78	22.79	1.01	1.05
Elderly(ies)[4]	22.25	23.32	21.44	−1.88***	0.92	20.92	21.60	20.42	−1.19**	0.94
Elderly(ies) and adult(s)[5]	21.06	21.84	20.38	−1.46***	0.93	20.08	20.51	19.71	−0.79***	0.96
Region										
North	31.88	33.76	29.98	−3.78***	0.89	27.27	28.00	26.53	−1.47***	0.95
Northeast	27.53	28.90	26.25	−2.65	0.91	24.29	24.89	23.74	−1.14***	0.95
Center-west	15.23	15.85	14.63	−1.23***	0.92	15.64	15.77	15.52	−0.25	0.98
Southeast	12.62	12.88	12.38	−0.50	0.96	15.25	15.24	15.27	0.03	1.00
South	9.06	8.88	9.24	0.35***	1.04	10.01	9.80	10.21	0.40*	1.04

Table 3 (continued)

Variables	Standard MPI					Fuzzy				
	H (%)			Differences					Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Color/ethnicity										
White	11.64	11.91	11.40	− 0.51***	0.96	13.28	13.31	13.25	− 0.07	1.00
Black	22.82	24.02	21.60	− 2.42	0.90	22.14	22.28	22.00	− 0.29	0.99
Asian	6.89	6.94	6.85	− 0.10***	0.99	8.11	7.29	8.70	1.41	1.19
Brown	23.32	24.08	22.59	− 1.49	0.94	21.88	22.11	21.66	− 0.44*	0.98
Indigenous	22.15	21.87	22.40	0.54***	1.02	21.99	21.37	22.56	1.18	1.06
Undeclared	29.27	36.66	21.54	− 15.12***	0.59	22.67	26.82	18.33	− 8.49*	0.68
Area type										
Urban	14.62	14.91	14.36	− 0.55***	0.96	16.54	16.57	16.51	− 0.07	1.00
Rural	37.73	39.24	36.11	− 3.13***	0.92	26.66	27.23	26.04	− 1.18***	0.96

Significance levels: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. Fuzzy outcomes represent degrees of poverty. Standard errors are available under request. 1. "Single" refers to adults only. 2. Only adult couples, and with or without other adults in the household. 3. No couples as primary members of the household. 4. With or without children. 5. At least one adult and with or without children

Table 4 Multidimensional poverty estimations and gender differences for the Economic Autonomy Index by subgroup

Variables	Economic autonomy index					Fuzzy				
	H (%)			Differences					Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Total	33.49	32.26	34.66	2.40***	1.07	33.49	32.65	34.29	1.64***	1.05
Household headship										
Male-headed	30.97	27.95	34.54	6.59***	1.24	31.77	29.52	34.41	4.89***	1.17
Female-headed	37.23	40.90	34.79	−6.11***	0.85	36.06	38.92	34.15	−4.77***	0.88
Age groups										
Child	30.43	30.73	30.11	−0.61	0.98	30.23	30.45	29.99	−0.46	0.98
Adult	37.36	35.89	38.74	2.86***	1.08	36.72	35.59	37.78	2.19***	1.06
Elderly	22.05	18.58	24.80	6.22***	1.33	24.97	23.16	26.40	3.24***	1.14
Family composition										
Single without children[1]	30.65	32.67	27.85	−4.81**	0.85	30.57	32.01	28.58	−3.43**	0.89
Single with children[1]	58.92	62.00	57.22	−4.78**	0.92	46.74	48.97	45.50	−3.46**	0.93
Couple without children[2]	30.35	29.09	31.73	2.64***	1.09	31.24	30.32	32.26	1.94***	1.06
Couple with children[2]	34.85	33.18	36.56	3.38***	1.10	34.40	32.98	35.87	2.89***	1.09
Adults without children[3]	35.92	37.19	34.93	−2.26	0.94	35.95	37.51	34.74	−2.77***	0.93
Adults with children[3]	48.12	47.08	48.82	1.74	1.04	44.53	43.32	45.34	2.02***	1.05
Elderly(ies)[4]	18.00	15.22	20.09	4.87***	1.32	21.55	20.41	22.40	1.99***	1.10
Elderly(ies) and adult(s)[5]	31.29	30.91	31.63	0.72	1.02	32.68	32.62	32.74	0.12	1.00
Region										
North	42.28	41.81	42.75	0.94	1.02	39.97	39.33	40.61	1.28***	1.03
Northeast	42.77	42.30	43.20	0.90**	1.02	41.16	40.76	41.53	0.78***	1.02
Center-west	33.28	31.89	34.61	2.72***	1.09	32.36	31.42	33.27	1.85***	1.06
Southeast	30.08	28.23	31.77	3.54***	1.13	30.81	29.67	31.86	2.19***	1.07
South	20.73	19.25	22.14	2.90***	1.15	23.53	22.51	24.50	2.00***	1.09

Table 4 (continued)

Variables	Economic autonomy index									
	H (%)			Differences		Fuzzy			Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Color/ethnicity										
White	25.23	23.81	26.52	2.71***	1.11	26.72	25.97	27.39	1.42***	1.05
Black	40.24	38.86	41.64	2.78***	1.07	39.26	38.17	40.36	2.19***	1.06
Asian	21.48	14.06	26.71	12.65***	1.90	22.31	18.79	24.78	5.99**	1.32
Brown	40.23	38.94	41.47	2.53***	1.06	39.00	37.87	40.08	2.21***	1.06
Indigenous	36.97	34.18	39.51	5.33	1.16	35.77	33.52	37.82	4.31	1.13
Undeclared	41.40	44.65	38.00	− 6.65	0.85	39.28	40.76	37.73	− 3.02	0.93
Area type										
Urban	31.46	30.09	32.71	2.62***	1.09	31.76	30.84	32.60	1.77***	1.06
Rural	45.28	43.81	46.87	3.06***	1.07	43.53	42.31	44.86	2.55***	1.06

Significance levels: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. Fuzzy outcomes represent degrees of poverty. Standard errors are available under request. 1. "Single" refers to adults only. 2. Only adult couples, and with or without other adults in the household. 3. No couples as primary members of the household. 4. With or without children. 5. At least one adult and with or without children

Table 5 Inequality among the multidimensionally poor and gender differences for the Standard MPI by subgroup

Variables	Standard MPI									
	I_q			Differences		I_{fz}			Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Total	0.0233	0.0239	0.0226	−0.0013***	0.95	0.0193	0.0199	0.0186	−0.0012***	0.94
Household headship										
Male-headed	0.0236	0.0243	0.0226	−0.0017***	0.93	0.0174	0.0185	0.0161	−0.0024***	0.87
Female-headed	0.0229	0.0233	0.0226	−0.0007	0.97	0.0221	0.0228	0.0216	−0.0012	0.95
Age groups										
Child	0.0184	0.0188	0.0180	−0.0008	0.96	0.0172	0.0173	0.0171	−0.0002	0.99
Adult	0.0241	0.0247	0.0234	−0.0013**	0.95	0.0182	0.0191	0.0173	−0.0017***	0.91
Elderly	0.0242	0.0255	0.0232	−0.0023***	0.91	0.0267	0.0281	0.0257	−0.0024*	0.91
Family composition										
Single without children[1]	0.0322	0.0337	0.0298	−0.0038	0.89	0.0243	0.0259	0.0220	−0.0039	0.85
Single with children[1]	0.0235	0.0265	0.0220	−0.0045	0.83	0.0238	0.0267	0.0222	−0.0044	0.83
Couple without children[2]	0.0227	0.0233	0.0220	−0.0013	0.95	0.0155	0.0167	0.0142	−0.0025***	0.85
Couple with children[2]	0.0225	0.0227	0.0223	−0.0004	0.98	0.0164	0.0170	0.0157	−0.0014**	0.92
Adults without children[3]	0.0256	0.0289	0.0231	−0.0058**	0.80	0.0222	0.0230	0.0215	−0.0015	0.94
Adults with children[3]	0.0207	0.0206	0.0207	0.0001	1.00	0.0239	0.0227	0.0247	0.0021	1.09
Elderly(ies)[4]	0.0240	0.0252	0.0231	−0.0021**	0.92	0.0248	0.0273	0.0230	−0.0043***	0.84
Elderly(ies) and adult(s)[5]	0.0237	0.0243	0.0231	−0.0012*	0.95	0.0221	0.0228	0.0214	−0.0013	0.94
Region										
North	0.0289	0.0302	0.0274	−0.0028***	0.91	0.0395	0.0427	0.0364	−0.0063***	0.85
Northeast	0.0246	0.0254	0.0238	−0.0016***	0.94	0.0305	0.0323	0.0289	−0.0034***	0.89
Center-west	0.0216	0.0221	0.0211	−0.001	0.95	0.0126	0.0126	0.0126	0.000	1.00
Southeast	0.0198	0.0197	0.0200	0.0002	1.01	0.0131	0.0129	0.0133	0.0004	1.03
South	0.0189	0.0193	0.0186	−0.0007	0.96	0.0072	0.0065	0.0079	0.0014*	1.21

Table 5 (continued)

Variables	Standard MPI					I_{fz}				
	I_q			Differences					Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Color/ethnicity										
White	0.0206	0.0208	0.0204	− 0.0005	0.98	0.0112	0.0116	0.0109	− 0.0007	0.94
Black	0.0260	0.0261	0.0259	− 0.0002	0.99	0.0278	0.0282	0.0274	− 0.0008	0.97
Asian	0.0225	0.0205	0.0240	0.0034	1.17	0.0064	0.0074	0.0057	− 0.0017	0.77
Brown	0.0240	0.0249	0.0231	− 0.0018***	0.93	0.0253	0.0258	0.0248	− 0.0011	0.96
Indigenous	0.0158	0.0174	0.0144	− 0.0030	0.83	0.0244	0.0200	0.0284	0.0084*	1.42
Undeclared	0.0211	0.0242	0.0157	− 0.0085**	0.65	0.0312	0.0505	0.0110	− 0.0395***	0.22
Area type										
Urban	0.0211	0.0214	0.0208	− 0.0006	0.97	0.0157	0.0158	0.0157	− 0.0001	0.99
Rural	0.0280	0.0290	0.0270	− 0.0020***	0.93	0.0396	0.0417	0.0372	− 0.0045***	0.89

Significance levels: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. Standard errors are available under request. 1 "Single" refers to adults only. 2. Only adult couples, and with or without other adults in the household. 3. No couples as primary members of the household. 4. With or without children. 5. At least one adult and with or without children

Table 6 Inequality among the multidimensionally poor and gender differences for the economic autonomy index by subgroup

Variables	Economic autonomy index					I_{fz}				
	I_q			Differences					Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Total	0.0232	0.0230	0.0234	0.0004	1.02	0.0438	0.0398	0.0476	0.0079***	1.20
Household headship										
Male-headed	0.0222	0.0219	0.0226	0.0007	1.03	0.0414	0.0336	0.0506	0.0170***	1.51
Female-headed	0.0244	0.0245	0.0243	−0.0002	0.99	0.0474	0.0521	0.0443	−0.0079***	0.85
Age groups										
Child	0.0247	0.0246	0.0249	0.0003	1.01	0.0276	0.0291	0.0259	−0.0032***	0.89
Adult	0.0220	0.0219	0.0220	0.0002	1.01	0.0497	0.0452	0.0539	0.0088***	1.19
Elderly	0.0287	0.0281	0.0291	0.0010	1.03	0.0432	0.0334	0.0508	0.0174***	1.52
Family composition										
Single without children[1]	0.0205	0.0205	0.0204	−0.0002	0.99	0.0375	0.0395	0.0347	−0.0048	0.88
Single with children[1]	0.0455	0.0479	0.0440	−0.0039	0.92	0.0852	0.0981	0.0780	−0.0201***	0.80
Couple without children[2]	0.0201	0.0207	0.0196	−0.0010	0.95	0.0388	0.0353	0.0426	0.0073***	1.21
Couple with children[2]	0.0226	0.0228	0.0223	−0.0005	0.98	0.0430	0.0387	0.0474	0.0087***	1.22
Adults without children[3]	0.0225	0.0220	0.0229	0.0009	1.04	0.0483	0.0494	0.0475	−0.0020	0.96
Adults with children[3]	0.0217	0.0223	0.0213	−0.001	0.95	0.0556	0.0518	0.0581	0.0062	1.12
Elderly(ies)[4]	0.0259	0.0257	0.0260	0.0003	1.01	0.0330	0.0254	0.0387	0.0132***	1.52
Elderly(ies) and adult(s)[5]	0.0217	0.0207	0.0227	0.0020**	1.09	0.0438	0.0392	0.0479	0.0086***	1.22
Region										
North	0.0228	0.0227	0.0230	0.0003	1.01	0.0497	0.0473	0.0521	0.0048***	1.10
Northeast	0.0240	0.0239	0.0242	0.0003	1.01	0.0547	0.0509	0.0582	0.0073***	1.14
Center-west	0.0232	0.0220	0.0242	0.0022*	1.10	0.0407	0.0362	0.0450	0.0088***	1.24
Southeast	0.0226	0.0225	0.0226	0.0001	1.00	0.0412	0.0365	0.0456	0.0091***	1.25
South	0.0231	0.0226	0.0236	0.0010	1.05	0.0288	0.0254	0.0321	0.0067***	1.26

Table 6 (continued)

Variables	Economic autonomy index					I_{fz}				
	I_q			Differences					Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Color/ethnicity										
White	0.0216	0.0210	0.0221	0.0011*	1.05	0.0335	0.0294	0.0373	0.0079****	1.27
Black	0.0256	0.0257	0.0255	−0.0003	0.99	0.0555	0.0524	0.0587	0.0064**	1.12
Asian	0.0286	0.0312	0.0276	−0.0036	0.88	0.0421	0.0369	0.0458	0.0089	1.24
Brown	0.0237	0.0235	0.0238	0.0003	1.01	0.0512	0.0466	0.0557	0.0092***	1.20
Indigenous	0.0209	0.0230	0.0192	−0.0038	0.84	0.0429	0.0420	0.0437	0.0016	1.04
Undeclared	0.0200	0.0198	0.0203	0.0005	1.02	0.0585	0.0633	0.0535	−0.0097	0.85
Area type										
Urban	0.0233	0.0233	0.0234	0.0001	1.01	0.0412	0.0375	0.0446	0.0071***	1.19
Rural	0.0227	0.0220	0.0234	0.0014**	1.06	0.0589	0.0516	0.0667	0.0151***	1.29

Significance levels: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. Standard errors are available under request. 1. "Single" refers to adults only. 2. Only adult couples, and with or without other adults in the household. 3. No couples as primary members of the household. 4. With or without children. 5. At least one adult and with or without children

Table 7 Household head's multidimensional poverty estimations and gender differences for the standard MPI by subgroup

Variables	Standard MPI					Fuzzy				
	H (%)			Differences					Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Total	21.39	20.53	22.60	2.07***	1.10	18.52	17.43	20.03	2.61***	1.15
Household headship										
Male-headed[1]	–	–	–	–	–	–	–	–	–	–
Female-headed[1]	–	–	–	–	–	–	–	–	–	–
Age groups										
Child[1]	–	–	–	–	–	–	–	–	–	–
Adult	19.69	18.94	20.81	1.87***	1.10	17.07	16.04	18.63	2.6***	1.16
Elderly	25.68	25.04	26.41	1.37	1.05	22.14	21.38	23.01	1.63***	1.08
Family composition										
Single without children[2]	17.62	18.93	15.80	−3.13**	0.83	17.86	18.24	17.34	−0.90	0.95
Single with children[2]	20.71	20.68	20.72	0.04	1.00	19.11	16.35	19.46	3.11	1.19
Couple without children[3]	16.75	16.64	17.10	0.46	1.03	15.57	15.50	15.78	0.28	1.02
Couple with children[3]	21.10	20.40	23.05	2.65***	1.13	16.49	15.95	18.02	2.07***	1.13
Adults without children[4]	18.38	15.13	19.57	4.43**	1.29	17.99	14.94	19.11	4.17***	1.28
Adults with children[4]	28.22	36.39	27.34	−9.06**	0.75	22.50	19.05	22.87	3.82*	1.20
Elderly(ies)[5]	23.33	23.83	22.80	−1.03	0.96	21.37	21.38	21.35	-0.03	1.00
Elderly(ies) and adult(s)[6]	25.53	24.27	26.90	2.64**	1.11	21.46	20.11	22.93	2.82***	1.14
Region										
North	37.65	39.74	34.78	−4.96***	0.88	27.82	28.40	27.02	−1.37	0.95
Northeast	34.44	34.17	34.77	0.6	1.02	26.00	25.29	26.86	1.57***	1.06
Center-west	19.11	19.17	19.01	−0.16	0.99	16.52	16.16	17.10	0.94	1.06
Southeast	15.03	13.93	16.68	2.75***	1.20	15.65	14.32	17.65	3.33***	1.23
South	11.00	9.85	12.54	2.69***	1.27	10.67	9.50	12.23	2.73***	1.29

Table 7 (continued)

Variables	Standard MPI					Fuzzy				
	H (%)			Differences					Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Color/ethnicity										
White	13.78	13.10	14.75	1.65**	1.13	13.26	12.25	14.73	2.47***	1.20
Black	26.12	25.85	26.46	0.61	1.02	23.02	21.93	24.38	2.46**	1.11
Asian	7.13	6.20	8.53	2.33	1.38	8.64	6.33	12.08	5.75**	1.91
Brown	28.15	27.22	29.44	2.22***	1.08	22.83	21.88	24.14	2.26***	1.10
Indigenous	24.08	21.78	27.49	5.71	1.26	21.96	19.49	25.61	6.12	1.31
Undeclared	25.04	17.21	32.87	15.65	1.91	17.04	14.69	19.39	4.69	1.32
Area type										
Urban	17.19	15.38	19.51	4.13***	1.27	16.92	15.40	18.89	3.49***	1.23
Rural	47.74	46.71	50.05	3.34***	1.07	28.49	27.75	30.16	2.41***	1.09

Significance levels: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. Fuzzy outcomes represent degrees of poverty. Standard errors are available under request. 1. Results are not applied for these categories because the data is restricted only to household heads. 2. "Single" refers to adults only. 3. Only adult couples, and with or without other adults in the household. 4. No couples as primary members of the household. 5. With or without children. 6. At least one adult and with or without children

Table 8 Household head's multidimensional poverty estimations and gender differences for the economic autonomy index by subgroup

Variables	Economic autonomy index									
	H (%)			Differences		Fuzzy			Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Total	27.98	25.67	31.19	5.52***	1.21	29.44	27.79	31.74	3.96***	1.14
Household headship										
Male-headed[1]	–	–	–	–	–	–	–	–	–	–
Female-headed[1]	–	–	–	–	–	–	–	–	–	–
Age groups										
Child[1]	–	–	–	–	–	–	–	–	–	–
Adult	33.01	29.61	38.14	8.53***	1.29	32.96	30.43	36.79	6.35***	1.21
Elderly	15.33	14.44	16.34	1.9**	1.13	20.58	20.24	20.97	0.74	1.04
Family composition										
Single without children[2]	30.65	32.67	27.85	– 4.81**	0.85	30.57	32.01	28.58	– 3.43**	0.89
Single with children[2]	50.91	36.50	52.72	16.22***	1.44	42.46	35.70	43.31	7.61***	1.21
Couple without children[3]	25.94	24.64	29.99	5.35***	1.22	27.54	26.51	30.76	4.24***	1.16
Couple with children[3]	34.22	32.12	40.14	8.02***	1.25	34.25	32.49	39.21	6.72***	1.21
Adults without children[4]	32.25	25.88	34.59	8.71***	1.34	32.36	27.88	34.01	6.13***	1.22
Adults with children[4]	47.76	37.80	48.84	11.04**	1.29	45.91	39.78	46.57	6.79**	1.17
Elderly(ies)[5]	12.57	11.79	13.39	1.6	1.14	18.27	18.32	18.22	-0.1	0.99
Elderly(ies) and adult(s)[6]	21.64	19.65	23.81	4.16***	1.21	25.34	23.85	26.96	3.1***	1.13
Region										
North	39.33	38.97	39.83	0.86	1.02	38.67	38.26	39.22	0.95	1.02
Northeast	37.42	35.17	40.13	4.96***	1.14	37.80	36.65	39.19	2.55***	1.07
Center-west	28.17	27.11	29.85	2.74*	1.10	28.44	27.65	29.70	2.05*	1.07
Southeast	24.42	22.15	27.83	5.67***	1.26	26.36	24.60	29.00	4.4***	1.18
South	16.76	13.81	20.73	6.92***	1.50	20.30	18.16	23.18	5.02***	1.28

Table 8 (continued)

Variables	Economic autonomy index									
	H (%)			Differences		Fuzzy			Differences	
	Total	Male	Female	Absolute	Relative	Total	Male	Female	Absolute	Relative
Color/ethnicity										
White	19.53	17.96	21.80	3.84***	1.21	22.29	21.24	23.81	2.58***	1.12
Black	34.39	31.93	37.46	5.53***	1.17	35.37	33.52	37.68	4.16***	1.12
Asian	14.45	8.81	22.84	14.03***	2.59	15.10	12.90	18.37	5.47*	1.42
Brown	35.12	32.44	38.80	6.35***	1.20	35.38	33.40	38.09	4.69***	1.14
Indigenous	32.30	26.41	41.00	14.59*	1.55	35.14	31.86	39.99	8.13	1.26
Undeclared	28.34	28.68	28.00	-0.68	0.98	29.27	29.49	29.05	-0.44	0.99
Area type										
Urban	26.31	23.35	30.14	6.79***	1.29	27.84	25.63	30.69	5.06***	1.20
Rural	38.44	37.51	40.53	3.01**	1.08	39.48	38.75	41.13	2.38***	1.06

Significance levels: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. Fuzzy outcomes represent degrees of poverty. Standard errors are available under request. 1. Results are not applied for these categories because the data is restricted only to household heads. 2. "Single" refers to adults only. 3. Only adult couples, and with or without other adults in the household. 4. No couples as primary members of the household. 5. With or without children. 6. At least one adult and with or without children

As for the EAI outcomes (Table 8), in total, multidimensional poverty for women is between 14% and 21% higher than for men. Similar to the SMPI, in both approaches, the Asian, Indigenous, and South categories have the highest relative differences disfavoring women. In the household head perspective, we can observe that female household heads with children, especially single (both living with or without other adults), have the worst outcomes and the highest absolute disparities within the Family Composition subgroup in the EAI.

4.3 Estimations for Couples: Intracouple Perspective

This subsection focuses on the outcomes of the primary female with respect to her partner (for adult- or elderly-heterosexual-couples living in the same household). Because social norms significantly contribute to decisions within households, especially between couples (Bertrand et al., 2015; Codazzi et al., 2018), the intracouple perspective allows us to go deeper into the intrahousehold analysis.

Figure 2 and 3 show the female-male difference in means by intervals of deprivation scores and membership degrees for the SMPI and EAI, respectively. The aim is to analyze the intracouple disparities for people with low/moderate deprivation or membership degree (interval from 0 to 0.333), moderate/high deprivation or membership degree (interval from 0.333 to 0.666), and high/very high deprivation or membership degree (interval from 0.666 to 1).
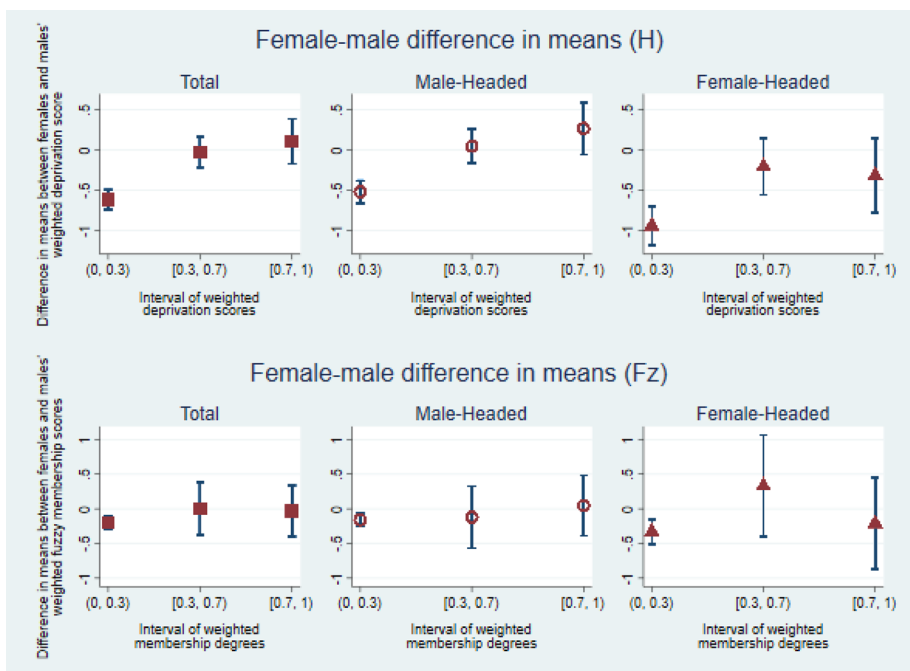
Fig. 2 Female-male difference in means for the Standard MPI by intervals of weighted deprivation scores and fuzzy membership degrees. Note: Capped spikes for T-test confidence intervals (upper and lower 95% confidence limits)
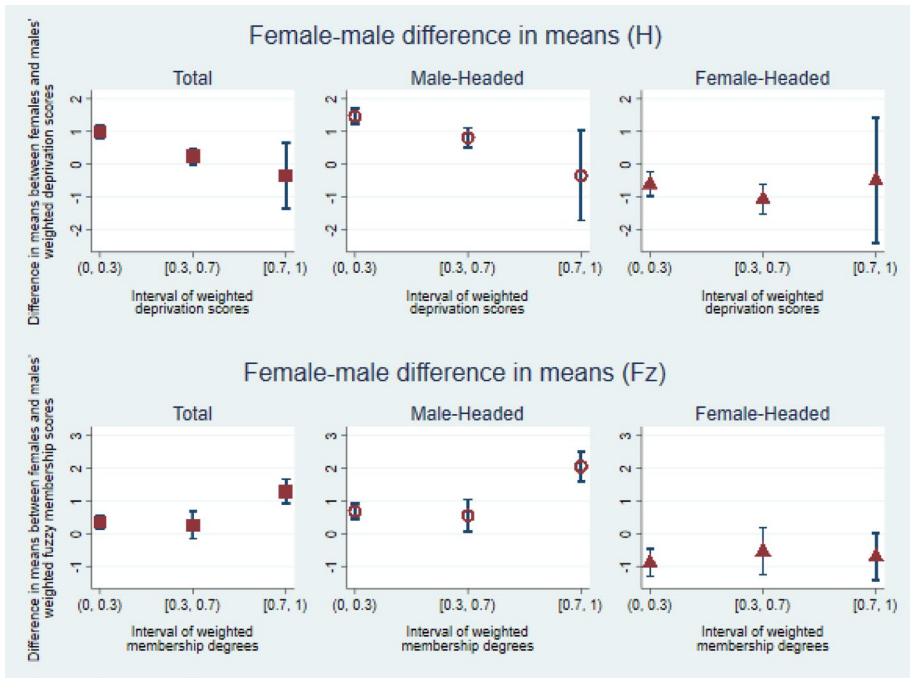
Fig. 3 Female-male difference in means for the Economic Autonomy Index by intervals of weighted deprivation scores and fuzzy membership degrees. Note: Capped spikes for T-test confidence intervals (upper and lower 95% confidence limits)

Concerning the EAI results (Fig. 3), in most intervals, women are at a disadvantage when their partners are the household head (male-headed), and women are at an advantage when they are the household head (female-headed).

To further understand the intracouple gender gaps in households, Table 9 shows the results for the Gender Gap Index (GGI), the Fuzzy Gender Gap Index (Fz_{GGI}), and their components. For the SMPI outcomes, the total share of women lacking gender parity, H_{GGI}, is 2%, with an average gap of 24 pp. These results increase when women are the household head. As for the fuzzy estimations, which account for all the households regardless of poverty status, the total share of households with women in disadvantage, H_{FzGGI}, is 27%, but the average gap is smaller than the previous results (6 pp). For the fuzzy approach, the share of women at a disadvantage is smaller in female-headed households than in male-headed households, but the average gap is larger for female-headed households.

Regarding the EAI outcomes, the total share of women lacking gender parity is 22%, with an average gap of 23%. For the fuzzy approach, the total share of women at a disadvantage is 56%, and the average gender gap is 33 pp. Interestingly, the outcomes for women are considerably better when they are the household head. For instance, the GGI is 3% in female-headed households, while 6% in male-headed households, and 5% in total. This pattern is even more apparent in the fuzzy results, as the FzGGI is 12% in female-headed households, while 21% in male-headed households, and 18% in total.

Table 9 Intracouple gender gap measures for the standard MPI and the economic *autonomy index*

Measures	Standard MPI			Economic autonomy index		
	Total	Male-headed	Female-headed	Total	Male-headed	Female-headed
Share of women lacking gender parity (H_{GGI})[1]	2.59%	2.53%	2.78%	22.41%	24.87%	15.10%
	(0.001)	(0.001)	(0.002)	(0.003)	(0.004)	(0.005)
Average female-male gender gap (I_{GGI})	23.86%	23.84%	23.92%	23.32%	23.86%	20.70%
	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)
Gender gap index (GGI)	0.0061	0.0059	0.0065	0.0521	0.0591	0.0311
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Share of disadvantaged women (H_{FzGGI})[2]	26.92%	28.43%	22.46%	55.51%	61.23%	38.54%
	(0.003)	(0.004)	(0.006)	(0.004)	(0.005)	(0.007)
Average female-male fuzzy gender gap (I_{FzGGI})	6.16%	5.93%	7.05%	33.30%	33.84%	30.76%
	(0.002)	(0.002)	(0.003)	(0.004)	(0.004)	(0.007)
Fuzzy gender gap index (FzGGI)	0.0164	0.0167	0.0157	0.1841	0.2064	0.1181
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Linearized standard errors considering the survey design in round brackets. 1. When the female is multidimensionally poor, and her new censored deprivation score is higher than the one of her partner (for more details see the Sect. 2.4). 2. When the poverty membership degree of the primary female is higher than her partner (for more details see the Sect. 2.4)

5 Conclusion

This paper contributes to the literature on multidimensional poverty measurement by applying and proposing procedures that, combined, enhance gender differences estimations considering the limitations of household surveys. This analysis focuses on Brazil and the main findings are the following.

If we look only to the SMPI for the whole population, poverty appears not to be feminized, as men are poorer than women in most subgroups. However, if we look to other perspectives and the EAI, women are mostly at a disadvantage. In the EAI estimation, women are worse off in all the perspectives (whole population, household head, and couples) in most subgroups. In the interhousehold perspective, female household heads are poorer in most subgroups in both the indexes (SMPI and EAI). These results suggest that women are worse off than men in terms of employment and time quality, economic security, and access to resources—which are crucial aspects of agency or degree of empowerment.

Moreover, in most specifications, individuals living in female-headed households are poorer than those living in male-headed households, but in female-headed households, women are at an advantage compared to men, or at least the disparity decreases. In the intracouple EAI gender gap estimations, the outcomes considerably improve when women are the household head.

The previous outcomes reveal the importance of considering different subgroups and indexes in multidimensional poverty analysis. Yet, this study represents one step in individual-based and gender differences analysis, as further improvements are possible. The main limitation of this study is the scarce availability of individual-level indicators in the Brazilian household budget survey, especially of health indicators. Consequently, the indexes here are not entirely at the individual level, but they are a mix of individual and household level indicators, which can bias the gender differences analysis. In addition, to build individual-level indicators for the whole population, this study relies on assumptions about the impact of adults' deprivations on children living in the same household.

As policy implications, this study suggests that social policies should concern the situation of women, especially in the dimensions of Quality of Employment and Resources, and considering the geographical and racial inequalities. However, policy interventions must always ensure that it does not create further disadvantages such as increasing female workload or reinforcing gender roles. Aspects that should receive further research and policy consideration are understanding why people living in female-headed households are poorer than male-headed households, and why gender disparities disfavoring women are higher in male-headed households.

Moreover, by proposing individual-based indicators, this study does not imply that households are merely a place where a group of autonomous individuals live together. Instead, we are aware that they are usually a place of cooperation, care, sharing, and financial benefits due to economies of scale in production and consumption (Doss, 2021). Therefore, policies should contemplate collective forms of agency, recognize that care is central to our society and economy, and ensure universal access to care with gender-balanced responsibilities.

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Declarations

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