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ORIGINAL RESEARCH

Vulnerability to Multidimensional Poverty: An Application to Colombian Households

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Abstract
This paper analyzes Colombian households' vulnerability to multidimensional poverty. For this purpose, we apply the vulnerability as expected poverty approach and the multidimensional poverty index to obtain the probability of a household being poor in the future. The source of information was the Colombian Longitudinal Survey. By employing the Feasible Generalized Least Squares methodology in three stages, the results indicate that the percentage of vulnerable households is greater than the percentage of poor households. In addition, the pattern of vulnerability differs depending on the area (i.e., rural or urban) in which the households are located. These findings have important policy implications; specifically, they enable us to distinguish between groups of people that require particular policy strategies: households that are persistently poor require poverty alleviation interventions and those that are not poor, but have a high probability of becoming poor in the future, need poverty prevention strategies.

Keywords Vulnerability to poverty · Multidimensional poverty · Household deprivation · Vulnerability to multidimensional poverty

1 Introduction

Eliminating poverty is a developmental goal on the agendas of local, regional, and national governments. In Colombia, monetary poverty decreased from 42% in 2008 to 27% in 2018 (DANE, 2019a), and the multidimensional poverty index (MPI) decreased 10.8 percentage points over the 2010–2018 period (DANE, 2019b). However, this progress in poverty reduction stalled in 2019, when monetary poverty increased even before the pandemic (35.7%), reaching 42.5% in 2020 (this is the last official poverty indicator, DANE (2021)). Moreover, considering the head of households, the incidence of poverty is worse for women (46.7%), people 25 years old or younger (50.5%), individuals with primary education or no schooling (49.6%), unemployed (69.1%), and self-employed (50.9%) (DANE, 2021).

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Poverty has a stochastic nature, which means that the current non-poor population may or may not be poor in the future. One of the seminal papers about this characteristic of poverty was published by Chaudhuri et al. (2002), followed by several authors of more recent contributions such as Bayudan-Dacuycuy and Lim (2014), Ward (2016), and Sahasranaman (2021). There is a segment of the population identified as non-poor that faces a high probability of suffering an adverse shock and, by experiencing that situation, can become part of the poor population in the future. The last affirmation has been especially evident in the pandemic, which has revealed a hidden poverty phenomenon that affects households no previously classified as poor. Núñez (2020) estimates that, in Colombia, the pandemic will increase the number of poor to 22 million and the number of absolute poor to almost 6 million.

Some approaches have been proposed in this line of the literature to measure the risk that households face of falling into poverty or remaining poor. One of those is the VEP approach, which defines vulnerability as the probability that a household will be poor in the future, regardless of whether it is poor today. This vulnerability is characterized as an ex-ante measure of poverty and is therefore not simultaneously observable, unlike conventional poverty measures.

Some of the studies addressing vulnerability use the monetary poverty line as a reference (Novignon & Jacob2010; Gaiha & Imai, 2008; Azeem et al., 2017; Gang et al., 2018; Mba et al., 2018), including a couple of works analyzing the Colombian case (Castaño, 2007; Núñez & Espinosa, 2005). However, over the last few decades, an international consensus has been agreed upon that poverty goes far beyond the lack of income because a poor person may have several deprivations at a certain point in time (Decancq et al., 2020). As a result, the global MPI is currently available for several countries, including Colombia. Since 2012, the National Administrative Department of Statistics (DANE is the Spanish acronym) has estimated the MPI for Colombia by employing the methodology proposed by Alkire and Foster (2011).

The recent literature has incorporated the variable of multidimensional poverty to estimate the vulnerability to poverty of households (Azeem et al., 2018; Feeny & McDonald, 2016). As far as we know, ours is the first study to apply this methodology to analyze the Colombian context, characterized by regional disparities, high levels of informality, and credit market restrictions. As mentioned before, Núñez and Espinosa (2005) and Castaño (2007) have previously analyzed vulnerability to poverty in Colombia; however, they focus on monetary poverty instead of multidimensional poverty as we do. We therefore aim to answer the following questions: are non-poor households vulnerable to multidimensional poverty? Are households vulnerable to multidimensional poverty currently poor? What factors increase or reduce vulnerability to multidimensional poverty (VMP)? These are relevant questions in the current context, since one of the important lessons of the pandemic is that policymakers should not limit their efforts to combat poverty, because vulnerability to poverty is a phenomenon threatening the households' wellbeing as well. The reason is not only the probability of suffering additional future health negative shocks as the COVID-19, but the likeness of severe climate shocks, which will mainly affect poor population (Hallegatte et al., 2018).

We employed the Colombian Longitudinal Survey (ELCA) as an information source and the Feasible Generalized Least Squares (FGLS) method in three stages to estimate our models. The results show that the percentage of vulnerable households is higher than the percentage of poor households and that vulnerability presents different patterns according to the area—rural or urban—in which the households live. This finding has policy implications as follows: persistently poor households require poverty alleviation interventions and

vulnerable households (those that are not poor but have a high probability of being poor in the future) need poverty prevention strategies.

This document contains, in addition to the introduction, six additional sections. The following section sets forth the conceptual framework and the literature review. The third section explains the empirical strategy. The fourth section discusses data and the measurement of multidimensional poverty. The fifth section shows the results obtained for Colombia, and Sect. 6 concludes.

2 Theoretical Framework

2.1 Conceptual Overview

In very general terms, vulnerability can be defined as a condition of helplessness in which an adverse shock may affect individuals or households (Hoddinott & Quisumbing, 2003; Grimm et al., 2016). Therefore, a population with these conditions has two characteristics: the presence of internal weaknesses (context, personal) and the inability to face critical situations. In this sense, vulnerability may be understood as the risk that a household or individual will experience an episode of poverty over time. It differs from poverty because is related to the ex-ante risk of being poor, i.e. "before the veil of uncertainty has been revealed in a factual realisation of either a poverty or non-poverty state of nature" (Gallardo, 2022, p. 493).

Households vulnerable to poverty are those that may become poor either because of structural characteristics or because they are not prepared to face shocks (Gallardo, 2018 and 2022). However, the relationship between poverty and vulnerability may be ambiguous if the nature of each phenomenon is not understood. Dercon (2001) and Calvo and Dercon (2012) established that poverty, defined as the inability to achieve well-being, is an ex-post result of households that confronted various risks and undertook activities related to their assets or income (retrospective process). Conversely, vulnerability is the result of an ex-ante process that considers potential outcomes. That is, vulnerability refers to a future situation using present information (prospective exercise), which describes the exposure to poverty rather than the result of poverty per se.

Authors such as Klasen and Povel (2013), Hoddinott and Quisumbing (2003), and Gallardo (2018) comprehensively reviewed the works that are compatible with this line of research, finding several proposals to estimate vulnerability to poverty summarized in two approaches: vulnerability to expected low utility (VEU) and vulnerability as expected poverty (VEP).

The VEU is defined as the difference between a level of utility obtained with an amount of consumption sufficient for the household not to be considered vulnerable and the utility of current consumption. Through this initial definition, vulnerability can be broken down into (i) a measure of poverty, (ii) aggregate risk, which affects all households, and (iii) the idiosyncratic risk, which only affects individual households (Gallardo, 2018). In this regard, Hoddinott and Quisumbing (2003) raised two limitations of this type of approach. First, the dependence of a functional form of the utility function may clearly affect the estimations, and second, the result is in terms of units of utility, which can be confusing for policymakers.

In addition, Klasen and Povel (2013) mentioned that in the VEU approach, negative shocks have the same weight as positive shocks, which may compensate each other.

That is, some households can be identified as not vulnerable, even though they may face chronic poverty in the future. Therefore, taking current consumption as a benchmark, very rich and very poor households can be just as vulnerable if they have the same risk profile. In this regard, Gallardo (2018) suggested that the VEU approach has a symmetrical view of risk, which is not appropriate for addressing vulnerability because this phenomenon is associated with the inability to handle negative shocks. Thus, positive shocks that are irrelevant to vulnerability assessment should be discarded.

Several authors have attempted to overcome the mentioned disadvantages of this approach by maintaining the same framework of expected utility. For example, Calvo and Dercon (2005, 2007, 2012) took into account only states of nature below the poverty line. However, Gallardo (2018) indicated that the measurement of risk remains symmetrical, since its evaluation considers the deviations both higher and lower than the expected utility.

Another approach identified by Klasen and Povel (2013), Hoddinott and Quisumbing (2003), and Gallardo (2018) is VEP, which is known as the likelihood that households will fall into poverty in the future. We employ this approach in this study. While it is closely related to the World Bank's (2000) proposal, Klasen and Povel (2013) attributed this concept to Ravallion (1988) and Holzmann and Jorgensen (1999). According to them, vulnerability is the risk that an individual (or a household or community) will fall below the poverty line (i.e., underconsumption) or, for those already below the poverty line, will remain or fall deeper into poverty.

Nonetheless, with a more empirical rather than conceptual orientation, the most cited authors are Chaudhuri et al. (2002), who measured the probability that a household's future consumption is below the poverty line. The reason why this approach has been extensively employed—Azeem et al. (2018) for Pakistan; McCarthy et al. (2016) for Malawi; Novignon & Jacob (2010) for Ghana; Jamal & Haroon (2009) for Pakistan; Gaiha and Imai (2008) for India; Núñez and Espinosa (2005) and Castaño (2007) for Colombia; and Haughton and Khandker (2009) for several countries—is that estimations can be obtained using cross-sectional surveys, which are more frequent in developing countries than data panels (Gallardo, 2018). Additionally, this measurement strategy uses a risk threshold to identify vulnerable households (Azeem et al., 2018; Günther & Harttgen, 2009; Suryahadi & Sumarto, 2003).

However, both Klasen and Povel (2013) and Gallardo (2018) agreed on some limitations of this approach. First, VEP does not consider risk sensitivity, that is, households with the same vulnerability have the same expected outcome. For example, a household that will effectively receive the expected result should be less vulnerable than one that faces different possible future outcomes. Second, the severity of the expected poverty is not considered, as VEP only considers the probability of being below the poverty line without distinguishing whether it is far below or just below it. Finally, VEP estimates vulnerability assuming that past distributions reflect future distributions, for example, future consumption. In addition, all of the households concerned are exposed to the same distribution of changes in consumption, which is clearly a homogeneous exposure to risk. Despite these limitations, the method is useful because it enables public policymakers to easily identify households with a high probability of being poor in the future.

Conversely, Calvo (2008), Azeem et al. (2018), Feeny and McDonald (2016), and Gallardo (2020) have incorporated the MPI as a reference for the estimation of vulnerability indicators (other than the monetary poverty line). The motivation is that other forms of deprivation beyond consumption can affect well-being. This means that poverty must be understood as the inability to reach a minimum level of capacity to function (Sen, 1993).

In this context, it is necessary to analyze vulnerability to poverty in multidimensional terms. For this purpose, some authors use the VEU approach (Calvo, 2008; Gallardo, 2020) while others, such as Azeem et al. (2018), Tigre (2019), and Feeny and McDonald (2016), use the VEP approach, as we do in this paper, considering the VMP. This measurement strategy closely resembles that of Chaudhuri et al. (2002), with the difference that the measurement of poverty will be the weighted deprivation score of the MPI.

2.2 A summary of Previous Findings

In this section, the empirical findings of research related to household vulnerability are mentioned, mostly those focused on VEP and VMP.

Chaudhuri et al. (2002) argued that the ideal measure of vulnerability would be achieved using panel data; however, given the scarcity of this type of information in developing countries, the authors introduced the estimation of the vulnerability of households to poverty using cross-sectional data. To this end, they incorporate simplified assumptions into the consumption function of households. Using information from Indonesia, they concluded the following. First, the percentage of the total vulnerable population (45%) is considerably higher than that identified as poor (22%). Second, the distribution of vulnerable households differs strikingly from the distribution of poor households to different segments of the population. Third, the source of vulnerability in rural households was low average consumption prospects, while in urban households, vulnerability to poverty originated from consumption volatility.

Several studies have implemented the methodology for measuring the VEP, among others: Novignon and Jacob (2010) for Ghana, Jamal and Haroon (2009) for Pakistan, Gaiha and Imai (2008) for India, Hohberg et al. (2018) for Germany, Ward (2016) for China, and Castaño (2007) and Núñez and Espinosa (2005) for Colombia. The latter used the Colombian Quality of Life Survey in 2003, calculating that 39% of the Colombian population was vulnerable to monetary poverty, a percentage higher than the poverty rate. Finally, they found that vulnerability was greater in rural than in urban areas. However, Castaño (2007) used the Continuous Household Survey between 2001 and 2005, estimating that the vulnerable population decreased from 60 to 53%. He also found that the percentage of vulnerable and poor people in 2005 was 63% (i.e., there were 28 million people in need of public prevention and relief policies).

In Colombia, other methodologies have been used to identify vulnerable households. Balcázar et al. (2018), incorporated the vulnerability line to monetary poverty. Under this approach, the population considered vulnerable includes those above the poverty line and below the vulnerability line. This estimation strategy was suggested by López-Calva and Ortiz-Juarez (2014) based on the establishment of a threshold to define the middle class. The results show that the vulnerable population increased between 2008 and 2010 (14%), 2010 and 2012 (3.7%), and 2014 and 2016 (2.7%), wherein the percentage of the poor belonging to this population decreased each year (i.e., 59% of the vulnerable population in 2010 was poor in 2008 and 48% of the vulnerable population in 2016 was poor in 2014).

Regarding VMP, different methodologies have been implemented in several countries. Feeny and McDonald (2016) examined vulnerability on two small islands in Melanesia: the Solomon Islands and Vanuatu. This work was the first to measure VMP. As a benchmark, the authors employed the MPI developed by Alkire and Foster (2011)—which has become a widely accepted and used measure—together with the VEP approach (used by Chaudhuri et al., (2002), Christiaensen and Subbarao, (2005), and Suryahadi et al., (2000)). The

results suggest that a large proportion of households in these countries are vulnerable to experiencing multidimensional poverty (about 36%), and that the proportion of households that are likely to become poor in the future exceeds the proportion that is currently considered poor (21%).

In the same line, Mabrie (2018) estimated the VMP of urban households in Eastern Ethiopia in 2016 using a structural equations model and a Tobit model. The results revealed that the health and educational dimensions of the MPI contributed significantly to the VMP. In addition, the vulnerability of households is reduced if the household head is richer, better educated, healthier, and makes good decisions when confronted with economic shocks.

Gallardo (2020) proposed a model to measure the VMP. The methodology calculates an estimate of the probability that the household is not poor for each indicator of the MPI using a multilevel Probit model. He identified that Chile's vulnerable population in 2017 was 49%, while the multidimensionally poor population was 20% at the national level. This method differs from the approach suggested by Feeny and McDonald (2016) in which the calculation of the VMP is unidimensional, with an aggregate indicator of multiple deprivations. However, Gallardo (2020) recognizes that the latter approach is easier to estimate because parameterization decisions such as the level of risk are not required.

On the other hand, Azeem et al. (2018) examined the consistency of estimates of different ex post poverty measures (i.e., consumption-based monetary poverty and multidimensional poverty) and ex-ante poverty measures (i.e., vulnerability to monetary poverty and the VMP). The authors analyzed the synergies between the various approaches to poverty taking into account how difficult it can be to use the same set of data (i.e., consumption spending, dimensions). In addition, they discussed whether ex-post poverty measures identified the same poor households as the corresponding ex-ante vulnerability measures to poverty.

Their results showed that ex-post measures identified approximately two-fifths of the households as poor and the ex-ante measures identified approximately three-fifths of the households as vulnerable to poverty. Comparable estimates of overall poverty and vulnerability to poverty identified different households as poor and vulnerable. Although some agreement was found in the identification of households vulnerable to monetary poverty and multidimensional poverty, there is very little overlap in the identification of poor households in monetary and multidimensional terms. The percentage of poor households (26% monetary and 40% multidimensional) was lower than the percentage of households vulnerable to poverty (38% monetary and 55% multidimensional).

In summary, the estimates of household vulnerability to poverty performed in different countries have a common outcome: the population vulnerable to monetary poverty and multidimensional poverty exceeds the population identified as poor according to the poverty line and the MPI. As mentioned, the literature about the VMP is still scarce and does not exist in Colombia thus far. This is the main motivation of our study.

3 Empirical Strategy

In the VMP approach, vulnerability is understood as the probability of households to be multidimensionally poor in the future. Thus, the measurement of vulnerability requires estimating the mean and variance of a welfare measure, which we do by using Amemiya's FGLS methodology in three stages (1977). Our empirical strategy has several strengths:

first, it allows us to obtain the probability of households to be poor in a simple way, which makes easier to policy makers the identification of multidimensionally vulnerable households. Second, we use multidimensional poverty, whose reduction has become an important policy objective for governments in developing countries, including Colombia. Third, there is a growing amount of literature using FGLS methodology to study vulnerability in recent years (see for example Liu et al. (2021) and Tigre (2019)).

Chaudhuri et al. (2002) employed this methodology, by focusing in per capita consumption level of households to estimate vulnerability to monetary poverty. In this study, we follow Feeny and McDonald (2016), who applied the household deprivation score (d_i), as an indicator of well-being in an analysis of VMP:

$$d_i = X_i\beta + e_i \tag{1}$$

where d_i. represents household i's deprivation level d X_i are household's characteristics, including sociodemographic characteristics, main income sources, and ownership of assets. Households face different risks and have different risk management strategies. Therefore, the variation in the disturbance term e_i is interpreted as the intertemporal variation in well-being (Chaudhuri et al., 2002). Therefore, heteroscedasticity is allowed in the model by assuming that the variance of the disturbance term in the observed characteristics of household X_i is defined as:

$$\begin{aligned} \sigma^2_{e,i} &= X_i\theta + u_i \\ u_i &= N\left(0, \sigma^2_I\right) \end{aligned} \tag{2}$$

According to Feeny and McDonald (2016), the three-stage method is about obtaining consistent estimates of the error term to use them to transform the original model, so that the errors are homoscedastic. In the first stage, we use OLS to estimate Eq. 1; the square value of the residuals will be dependent variable in Eq. (2).

In the second stage, Eq. (2) is transformed in order to obtain asymptotically efficient FGLS estimates:

$$\frac{\hat{e}^2_{ols,i}}{X_i\hat{\theta}_{ols}} = \left(\frac{X_i}{X_i\hat{\theta}_{ols}}\right)\theta + \frac{u_i}{X_i\hat{\theta}_{ols}} \tag{3}$$

Finally, the last stage use predicted standard deviations $\hat{\sigma}_i = \sqrt{X_i\hat{\theta}_{FGLS}}$ (which is a consistent estimate of the variance of the error of household deprivation) produced in Eq. (3) to transform Eq. (1):

$$\frac{d_i}{\hat{\sigma}_i} = \left(\frac{X_i}{\hat{\sigma}_i}\right)\beta + \frac{u_i}{\hat{\sigma}_i} \tag{4}$$

In this way, we obtain the asymptotically efficient estimate of $\hat{\beta}_{FGLS}$. The vulnerability to poverty of a household in a certain period is given for

$$\hat{V}_{i,t} = \hat{P}_r(d_{i,t+1} > z|X_i) = \Phi\left(\frac{X_i\hat{\beta}_{FGLS} - k}{\sqrt{X_i\hat{\theta}_{FGLS}}}\right) \tag{5}$$

where $\widehat{V}_{i,t}$ is the probability that household *i*'s will have weighted deprivation counts above z in t+1; k is the conventional multidimensional poverty threshold (33% for the Colombian case, according to DNP (2012)); Φ is the probability density function of future deprivation. Finally, the results from the regression analysis will provide information on the key correlations about the vulnerability of households. These can be useful to guide policies and validate the impact of some variables that have already been identified in the literature.

4 Data

4.1 Data Gathering

As mentioned before, FGLS in three stages is employed to estimate the expected vulnerability in households using cross-sectional data. We use the ELCA, since it contains essential information to estimate the determinants of households' deprivation, such as late payments of household financial obligations, household shocks, and access to social programs. Although the data is available for the years 2010, 2013, and 2016, the required information to implement the methodology suggested by Feeny and McDonald (2016) was complete only for 2016.

The ELCA is representative at the national level for urban households in socioeconomic strata 1 to 4.[1] It is also representative for five geographic regions: Bogotá and the Central, Western, Atlantic, and Pacific regions. Conversely, rural households are representative for small agricultural producers in four regions: the Middle Atlantic region, the Cundiboyacense region, the Coffee region, and the West-center region. The sample size is 8,818 households (4,394 corresponds to the urban area and 4,424 to the rural area).

Table 1 summarizes the variables employed to estimate the VMP. Initially, a wealth index proposed by Filmer and Pritchett (2001) and calculated by Castaño et al. (2017) (available in the ELCA) was incorporated into the model. This indicator describes the level of wealth of a household represented in three dimensions—access to public services and public infrastructure, housing conditions, and use of durable assets.[2] This model also includes characteristics of the household head such as gender, years of education, and occupation. In addition, it incorporates some shocks that the household has experienced in the last three years and variables that are related to the well-being of the household, such as membership in social programs and possession of financial assets.

4.2 Approach to Multidimensional Poverty

The evaluation of household vulnerability is based on the multidimensional poverty measure suggested by Alkire and Foster (2011). These authors established a methodology for calculating poverty inspired by Amartya Sen's reflections on poverty as a phenomenon that goes beyond income in which several dimensions of poverty experienced by households

[1] There are six socioeconomic strata in Colombia; a value of 1 represents people with the lowest socioeconomic conditions.

[2] It was built using a principal component methodology in which the first principal component or asset index can take a positive or negative value and has no meaning per se (see Table 8).

Table 1 Variables and statistical summary. ELCA 2016

Variable	Rural N = 4224		Urban N = 4394		T-test of difference
	Mean	Standard Deviation	Mean	Standard Deviation	
MPI weighted deprivation score	0.301	0.119	0.189	0.128	42.28***
Wealth Index	0.415	1.641	−0.134	2.354	12.73***
Female-headed Household	0.768	0.422	0.601	0.489	17.13***
Dependency rate	0.646	0.673	0.565	0.622	5.82***
Years of education of the head of household	4.691	3.518	8.582	4.784	−43.50***
Private company employee	0.100	0.301	0.288	0.453	−22.92***
Worker on his own farm	0.193	0.395	0.009	0.094	30.13***
Self-employed	0.205	0.406	0.347	0.476	−14.83***
Beneficiary of MFA[a]	0.414	0.492	0.200	0.400	22.40***
Beneficiary of JA[a]	0.005	0.071	0.016	0.126	−5.09***
Credit card ownership	0.067	0.250	0.263	0.440	−25.75***
Accident or illness of a household member	0.293	0.455	0.301	0.458	−0.79
Death of the former head of household or spouse	0.023	0.151	0.015	0.124	2.64***
They had to leave their usual place of residence	0.060	0.237	0.071	0.256	−2.06**
Bankruptcy and/or closure of family business	0.018	0.134	0.037	0.190	−5.50***
Suffered floods, avalanches, landslides, overflows or gales	0.031	0.175	0.024	0.153	2.14**
Suffered tremors or earthquakes	0.035	0.184	0.034	0.182	0.17
Loss of employment	0.105	0.307	0.240	0.427	−17.00***
Delayed payment to public services companies	0.127	0.336	0.126	0.332	0.45
Delayed lease payments	0.003	0.061	0.013	0.117	−5.04***
Delayed payments to neighborhood stores	0.051	0.220	0.027	0.163	5.69***
Money in the bank	0.086	0.280	0.197	0.398	15.22***

[a]Más Familias en Acción (MFA) and Jóvenes en Acción (JA) are two conditional cash transfers programs in Colombia

Source: ELCA, 2016. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

are simultaneously analyzed. In this sense, the multidimensional poverty measurement approach recognizes the different types of deprivations suffered by households, such as lack of education, unemployment, inadequate health conditions, and low living standards. Households that are deprived of some dimensions are identified and the degree of deprivation required to be considered poor is established.

Alkire & Foster's methodology (2011) has become popular, with more than 100 countries using the MPI as a complementary measure of poverty. This is mainly due to two reasons: first, it satisfies the axiomatic properties of monotonicity and transference proposed by Sen (1976, 1979) that places it above the quality of life index and the unsatisfied basic needs index. Second, it is a flexible approach, since it is possible to select different dimensions that adapt to the environments of each country. The dimensions chosen for Colombia by the National Planning Department (DNP)—which considered the political constitution of Colombia, the variables used in other indicators applied in Latin America, a review of the dimensions applied to calculated indices in Colombia, and the availability of information (Angulo et al., 2011)—is an example of the second reason.

Specifically, Colombia's MPI has a weighted nested structure that contains six dimensions with the same weight (0.2): educational conditions of the household, conditions of children and youth, work, health, access to public home services, and housing conditions. Each of these dimensions is composed of indicators that have the same weight. Table 5 in the appendix summarizes the dimensions, indicators, and weights for the MPI.

A household will be considered poor if it is deprived in at least 33% of the indicators. This threshold is employed in Colombia for the official measurements of multidimensional poverty and has been widely accepted in other countries.

5 Results

5.1 Individual Correlations of the VMP

Table 2 presents the estimated coefficients of the mean and the variance of the percentage of weighted deprivation (see Eq. (4)) that are employed to estimate household vulnerability. Results in the table correspond to the total sample, a rural subsample, and an urban subsample.

Table 2 shows that households with a higher wealth index score tend to have lower expected poverty, and a similar effect is found on volatility. The opposite relationship was found with female-headed households, which are more vulnerable than male-headed in both rural and urban areas. There is also a negative correlation between the years of education of the head of household and the expected weighted deprivation. These results are in line with the official measures of poverty incidence in Colombia, which is higher for women (46.7% versus 40.1% for men)) and for individuals with primary education or no schooling (49.6% versus 15.7% for people with university and graduate education) (DANE, 2021).

Regarding the occupation of the head of household, the results are as expected, since households whose head is employed in a firm tend to have lower levels of deprivation; additionally, given their stable employment status, they also have lower volatility. In contrast, the self-employed worker will have higher levels of deprivation compared to other labor occupations in the urban area, although with lower volatility. Again, these results are aligned with official poverty measures in Colombia, which are higher for unemployed

Table 2 Model for estimating vulnerability to multidimensional poverty (MPV)

Dependent variable	Total		Urban		Rural	
	MPI weighted deprivation score	Variance	MPI weighted deprivation score	Variance	MPI weighted deprivation score	Variance
Wealth Index	−0.0115***	−0.0003***	−0.0088***	−0.0001	−0.0141***	−0.0001
	(0.0006)	(0.0001)	(0.0008)	(0.0001)	(0.0011)	(0.0002)
Female-headed Household	0.0206***	0.0012***	0.0149***	0.0015***	0.0205***	0.0006
	(0.0023)	(0.0004)	(0.0029)	(0.0004)	(0.0036)	(0.0006)
Dependency rate	0.0054***	0.0001	0.0071***	0.0004	0.0034	−0.0003
	(0.0017)	(0.0001)	(0.0025)	(0.0004)	(0.0023)	(0.0004)
Years of education of the household head	−0.0113***	−0.0001	−0.0111***	−0.0001	−0.0116***	−0.0001
	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0005)	(0.0001)
Private company employee	−0.0169***	−0.0005	−0.0106***	−0.0015***	−0.0113*	0.0020**
	(0.0030)	(0.0005)	(0.0037)	(0.0006)	(0.0058)	(0.0009)
Worker on his own field/farm	0.0023	−0.0016***	0.0484***	0.0016	−0.0027	−0.0009
	(0.0037)	(0.0006)	(0.0186)	(0.0027)	(0.0039)	(0.0006)
Self-employed	0.0286***	−0.0012***	0.0471***	−0.0029***	0.0066*	−0.0003
	(0.0026)	(0.0004)	(0.0034)	(0.0005)	(0.0040)	(0.0006)
Beneficiary of MFA	0.0429***	0.0014***	0.0379***	0.0008	0.0476***	0.0020***
	(0.0026)	(0.0004)	(0.0041)	(0.0006)	(0.0033)	(0.0005)
Beneficiary of JA	−0.0045	−0.0007	−0.0054	−0.0007	−0.0079	0.0004
	(0.0097)	(0.0015)	(0.0107)	(0.0016)	(0.0215)	(0.0035)
Credit card ownership	−0.0049*	−0.0005	−0.0098***	−0.0006	0.0009	−0.0005
	(0.0030)	(0.0005)	(0.0035)	(0.0005)	(0.0059)	(0.0009)
Accident or illness of a household member	0.0044*	0.0001	0.0033	0.0001	0.0037	−0.0003
	(0.0023)	(0.0004)	(0.0031)	(0.0005)	(0.0033)	(0.0005)
Death of the former head of household or spouse	−0.0060	−0.0006	−0.0070	0.0003	−0.0042	−0.0020
	(0.0072)	(0.0011)	(0.0111)	(0.0017)	(0.0097)	(0.0015)

Table 2 (continued)

Dependent variable	Total		Urban		Rural	
	MPI weighted deprivation score	Variance	MPI weighted deprivation score	Variance	MPI weighted deprivation score	Variance
They had to leave their usual place of residence	0.0119***	0.0013*	0.0076	0.0002	0.0169**	0.0025**
	(0.0045)	(0.0007)	(0.0057)	(0.0008)	(0.0072)	(0.0012)
Bankruptcy and/or closure of family business	0.0149**	0.0022**	0.0196**	0.0025**	0.0065	0.0013
	(0.0069)	(0.0011)	(0.0083)	(0.0012)	(0.0117)	(0.0019)
Suffered flooding, avalanches, landslides or gales	0.0042	−0.0001	0.0291***	0.0029*	−0.0101	−0.0021*
	(0.0065)	(0.0010)	(0.0110)	(0.0016)	(0.0075)	(0.0012)
Suffered tremors or earthquakes	0.0010	−0.0001	−0.0015	−0.0016	−0.0036	0.0001
	(0.0057)	(0.0009)	(0.0072)	(0.0011)	(0.0082)	(0.0013)
Loss of employment	0.0143***	0.0011**	0.0168***	0.0010*	0.0119**	0.0016*
	(0.0029)	(0.0005)	(0.0035)	(0.0005)	(0.0053)	(0.0008)
Delayed payment to public services companies	0.0212***	−0.0000	0.0179***	0.0002	0.0126**	−0.0006
	(0.0033)	(0.0005)	(0.0048)	(0.0007)	(0.0049)	(0.0008)
Delayed lease payments	0.0114	0.0014	0.0199	0.0031	−0.0117	−0.0040
	(0.0122)	(0.0019)	(0.0146)	(0.0022)	(0.0184)	(0.0030)
Delayed payments to stores	0.0177***	0.0013	0.0227**	0.0019	0.0164**	0.0010
	(0.0060)	(0.0009)	(0.0099)	(0.0015)	(0.0073)	(0.0012)
Money in the bank	0.0071**	0.0010**	0.0069*	0.0009*	0.0069	0.0013
	(0.0029)	(0.0005)	(0.0036)	(0.0005)	(0.0051)	(0.0008)
Urban	−0.0603***	−0.0005				
	(0.0027)	(0.0004)				
Atlantic		0.0003	0.0148***	0.0003		
		(0.0008)	(0.0052)	(0.0008)		

Table 2 (continued)

Dependent variable	Total		Urban		Rural	
	MPI weighted deprivation score	Variance	MPI weighted deprivation score	Variance	MPI weighted deprivation score	Variance
Eastern		−0.0008	0.0009	−0.0008		
		(0.0007)	(0.0048)	(0.0007)		
Central		−0.0018**	−0.0097**	−0.0018**		
		(0.0007)	(0.0048)	(0.0007)		
Pacific		−0.0004	0.0000	−0.0004		
		(0.0007)	(0.0049)	(0.0007)		
Mid—Atlantic					0.0180***	0.0001
					(0.0044)	(0.0007)
Cundi-boyacense					−0.0067	−0.0003
					(0.0042)	(0.0007)
Coffee region					0.0182***	0.0011
					(0.0047)	(0.0007)
Constant	0.2961***	0.0074***	0.2280***	0.0087***	0.2985***	0.0063***
	(0.0067)	(0.0010)	(0.0089)	(0.0013)	(0.0114)	(0.0018)
Adjusted R-Square	0.4827	0.0101	0.4483	0.0180	0.3057	0.010
Observations	8818		4394		4424	

Source ELCA, standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

individuals (69.1% versus 38.7% for occupied individuals), and for self-employed (50.9% versus 24.7% for wage earners). The estimations reveal the need of improving the social protection system in the country, with the purpose to guarantee the access to basic social services to the most vulnerable groups in the labor market.

Among the shocks that households presented during the study period, the loss of employment is significant for all samples, where households experiencing these shocks tend to have a higher level of expected poverty along with greater volatility of deprivation. Some of the analyzed shocks are significant in explaining the level of deprivation, weighted according to the area, such as the case of bankruptcy or closure of family businesses at the urban level and the need to leave the place of residence in the rural area, where households also have a higher level of variance of deprivation. How households cope with shocks and how governments help households cope with such shocks is an interesting topic, given that those coping strategies may prevent households from falling into poverty in the future (Ibañez & Moya, 2010; Arbeláez et al., 2019).

Households with a credit card tend to experience less vulnerability, although this relationship is only significant at urban areas. This might reflect the positive influence of households' financial inclusion. In fact, there is some empirical evidence for developing countries regarding the positive impact of financial inclusion on reducing vulnerability to poverty. In Ghana, for instance, Koomson et al. (2020) found that an increase in financial inclusion has positive effects on reducing vulnerability to poverty because it reduces by 28% the household's potential risk to fall into poverty. Moreover, an increase in financial inclusion has a bigger effect on reducing vulnerability to poverty in female-led households than in men-led households. In the same line, Dawood (2019) provide evidence of the positive impact of financial inclusion on reducing vulnerability to poverty in Indonesia. The authors find that financial credit reduces the risk of poverty for women-headed households because financial inclusion increases women's empowerment.

In addition, those households benefiting from "Más Familias en Acción", a conditional cash transfer program, have higher levels of deprivation on average. Several studies analyze the relationship between cash transfers and vulnerability of poverty. For example, Azeem et al. (2018) found that social protection has a positive and significant impact on poverty and vulnerability in Pakistan. Nonetheless, our result can be explained by the fact that the cash transfers programs have been assigned under a targeting strategy, that is, the most vulnerable families are the ones receiving this type of benefit.

In summary, important correlations were identified with the level of vulnerability of households that are consistent with some findings in the literature, such as years of schooling (Jha & Dang, 2010), dependency rate (Corbacho et al., 2007), job tenure (Mehar et al., 2016) and regional differences in poverty and vulnerability (Chaudhuri et al., 2002).

The correlations of some variables explain how certain policies oriented towards labor stability and access to credit can potentially reduce the vulnerability of households. Regarding female vulnerability, Garay and Espitia (2021) found that the current situation of women in the Colombian job market is worse than men´s situation. Women have lower probability of getting a job, and their labor conditions are worse. Thus, women experience greater socioeconomic vulnerability than men do, especially in the case female heads of households. As for credit access, the national government of Colombia has a program called *Banca de las Oportunidades*, whose main objective is to promote and facilitate financial inclusion in Colombia through access to services such as credits for families in conditions of vulnerability and poverty, small and medium-sized enterprises, and entrepreneurs (Banca de las Oportunidades, 2020). Our results support the necessity of these initiatives.

Table 3 Observed poverty and vulnerable population

		Observed poverty			
		Rural Population		Urban Population	
		n = 4424		n = 4394	
		Poor	Non-poor	Poor	Non-poor
		n = 1741	n = 2683	n = 620	n = 3774
		(39%)	(61%)	(14%)	(86%)
Estimated vulnerability	Vulnerable	87%	59%	56%	11%
		(1512)	(1593)	(349)	(400)
	Non- vulnerable	13%	41%	44%	89%
		(229)	(1090)	(271)	(3374)

Source: ELCA, own elaboration

5.2 Measures of Poverty and Vulnerability

After running the estimation using FGLS in three stages and calculating the probability of having a future deprivation weighted percentage greater than 33%, the vulnerable population in rural and urban areas was identified following the recommendations by Günther and Harttgen (2009) and Azeem et al. (2018). They suggested a vulnerability threshold of 0.29, which means that a household will be considered vulnerable if its estimated vulnerability $\widehat{V}_{ipm,i}$ exceeds 29%. Table 3 shows a brief characterization of the poor and non-poor populations in rural and urban areas. According to the available information, 39% of rural households and 14% of urban households experience multidimensional poverty.

Estimations reveal the critical situation in rural areas—87% of the currently poor population has a probability of being poor in the future of more than 29% (i.e., a large number of households are in chronic poverty or in a poverty trap). This result is explained because extreme inequalities persist in a large part of the rural areas of Colombia, where the lack of justice and property rights has generated continuous waves of violence that have affected these areas during the last century (Gordon et al., 2020). In this context, according to Berry (2017), land has become a vulnerable asset due to illegal appropriation by armed groups. In turn, both displacement and income insecurity affect the poor in rural areas in a particular way, since the poorest individuals cohabit on small and dispersed lands where the provision of public goods is scarce (Faguet et al., 2020).

This 87% of the population in rural areas requires poverty relief strategies that directly address their deprivations. Conversely, 13% of the poor households currently experience transitory poverty, therefore, they need poverty prevention policies to improve their situation.

As for urban areas, 56% of those households currently identified as poor are vulnerable to multidimensional poverty (i.e., they have a probability of more than 29% of remaining poor in the future). In this area, poverty is persistent due to social problems such as homelessness, overcrowding, child prostitution, and teenage pregnancy (Silva-Laya et al., 2020). In a multidimensional poverty context, those factors affect the education dimension, both by school attendance and by low educational achievement. According to this, poor urban households in Colombia have educational disadvantages

Table 4 Distribution of vulnerable households

		Estimated vulnerability			
		Rural Population		Urban Population	
		n = 4424		n = 4394	
		Vulnerable	Non-vulnerable	Vulnerable	Non- vulnerable
		n = 3105	n = 1319	n = 749	n = 3645
		(70%)	(30%)	(17%)	(83%)
Observed poverty	Poor	49%	17%	47%	7%
		(1512)	(229)	(349)	(271)
	Non-poor	51%	83%	53%	93%
		(1593)	(1090)	(400)	(3374)

Source: ELCA, own elaboration

that prevent them from freely exercising the right to education, since the poorest schools provide poor education. For this reason, Silva-Laya (2020) suggest to promote empathic institutions and adequate learning environments.

It is worth noting that in the urban area, households that are not currently poor but are vulnerable to becoming poor in the future represent 11% of the currently non-poor households. In contrast, the vulnerability situation is more evident in the rural area, in which approximately 59% of the households that are currently non-poor have a high probability of becoming poor in the future.

In summary, only 25% of the households in rural areas would not be the target for public policy. In contrast, the same proportion of urban households would require public intervention programs to overcome current, chronic, or future poverty.

Table 4 shows that the percentage of the population identified as vulnerable in the rural zone (70%) is greater than the population that is currently poor (39% in Table 3), with a less notable difference for the urban zone (17% vs. 14%). In this sense, these results coincide with those found by Chaudhuri et al. (2002), Núñez and Espinosa (2005), and Feeny and McDonald (2016).

A striking aspect is that about 50% of households identified as vulnerable were not identified as currently poor. This suggests that some households have not permanently overcome poverty since they may fall into poverty in the face of any major future shock. In this sense, social policy should deal with these households in a different way than those identified as chronically poor, since, in this case, a policy of poverty prevention (such as the granting of financial inclusion or job stability) is more appropriate than relief strategies. This need is consistent with findings from Urrea and Maldonado (2011), who analyzed the importance of savings, credit and insurance as protection mechanisms against income shocks in Colombia. As expected, credit is the main instrument that reduces the severe vulnerability of households. However, the poorest population does not have access to formal credit, which leads them to seek alternative financing through expensive informal credit.

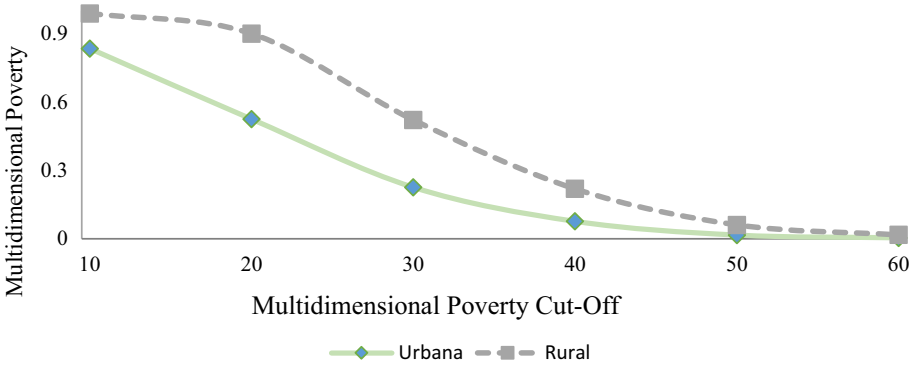

Fig. 1 Multidimensional poverty under different poverty lines (k). *Source* ELCA, own elaboration

5.3 Regional Disparities in Multidimensional Poverty and the VMP

In Colombia, multidimensional poverty measures are usually higher in rural areas than in urban areas. One explanation is the lack of public utilities, educational, and healthcare facilities. As previously mentioned, the results in the previous section were calculated by using the threshold (k) for values above 33% of the weighted deprivation; however, these results may be sensitive to different values of k. As a test of robustness, Fig. 1 shows the multidimensional poverty figures for different levels of k.

As observed, regional disparities remain for all levels of k. In other words, multidimensional poverty is greater in rural areas than in urban areas, regardless of the value of the threshold.

In addition, we checked the robustness of the index to changes in its specification to verify if the calculated index is a valid instrument for public policy analysis. Tables 6 and 7 in the Appendix show that comparisons are robust when using indices built with different weighting structures. In fact, high values of the Pearson, Spearman, and Kendall Tau b coefficients (close to 0.80) indicate that, in general, 80% of the poverty cases are identified by the index, in spite of changes in the weighting structure.

Figure 2 shows that the VMP is greater in rural areas than in urban areas. It should be noted that, for the multidimensional poverty cutoff, the probabilities established in Eq. (6) in Sect. 4 were recalculated. Regarding the vulnerability threshold, the analysis was not made for different levels, since, as stated by Günther and Harttgen (2009), the vulnerability threshold for a time horizon of $t+1$ is equal to 29%. For a longer time horizon, the vulnerability threshold would be 50%.

Finally, we show the results of multidimensional poverty and the VMP for five regions at the urban level: this includes the Atlantic, Eastern, Central, and Pacific regions as well as Bogota (see Fig. 3). As mentioned, the percentage of households that are vulnerable to future poverty exceeds the percentage with multidimensional poverty, except in the case of Bogota. This result is not surprising, since the labor, healthcare, and educational conditions in this city are notably different from those in the other subregions, specifically in terms of greater availability of jobs in the formal sector and higher accessibility to healthcare and educational institutions. The Atlantic region has the worst performance for both the current poor and those at risk of falling into poverty in the future. These results are evidence of the need to develop effective regional

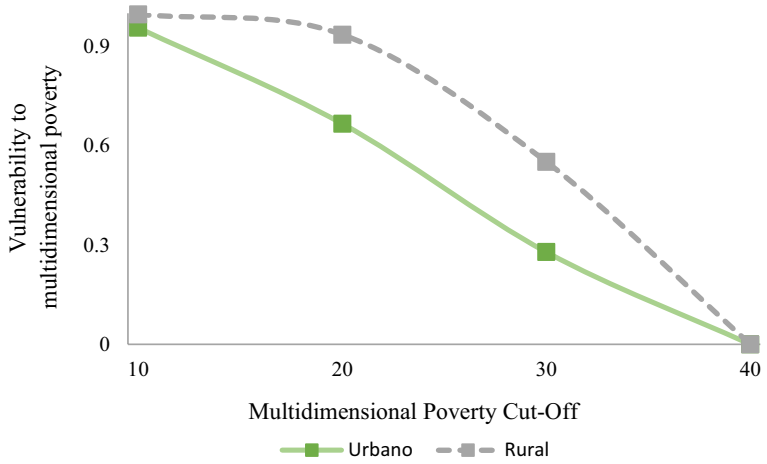

Fig. 2 Vulnerability to multidimensional poverty under different poverty lines (k). *Source* ELCA, own elaboration

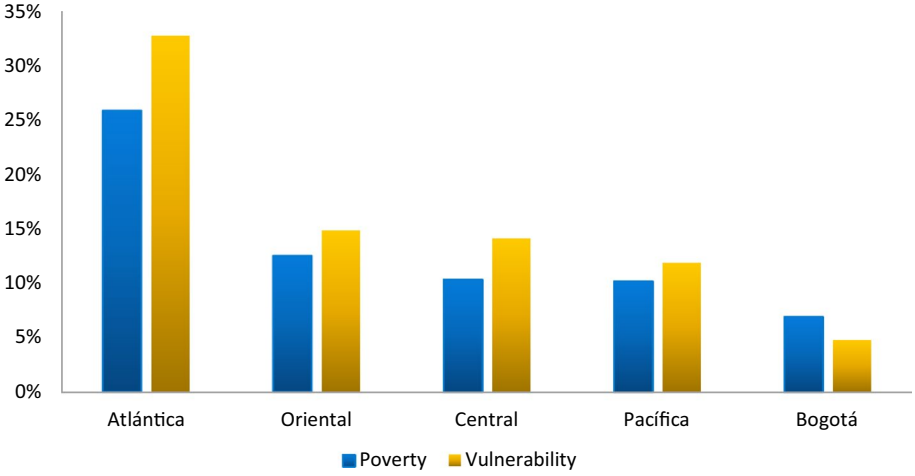

Fig. 3 Household in poverty (MPI) and vulnerability (VEMP) urban area. *Source* ELCA, own elaboration

policies that reduce the major disparities among the regions of the country. It seems like the developmental improvements that have occurred in Colombia over the last few decades have benefited the center at the expense of the periphery. Our results are aligned with those found by Turriago-Hoyos et al. (2020), who used the unsatisfied basic needs index as a measure of multidimensional poverty. According to their results, there is a center-periphery pattern in the index distribution and the the Caribbean coast presents the highest levels of deprivation.

For rural areas, the results are less heterogeneous among micro-regions (see Fig. 4). However, this is not a positive result since all of the regions present high percentages of multidimensional poverty. In addition, the levels of vulnerability are considerably

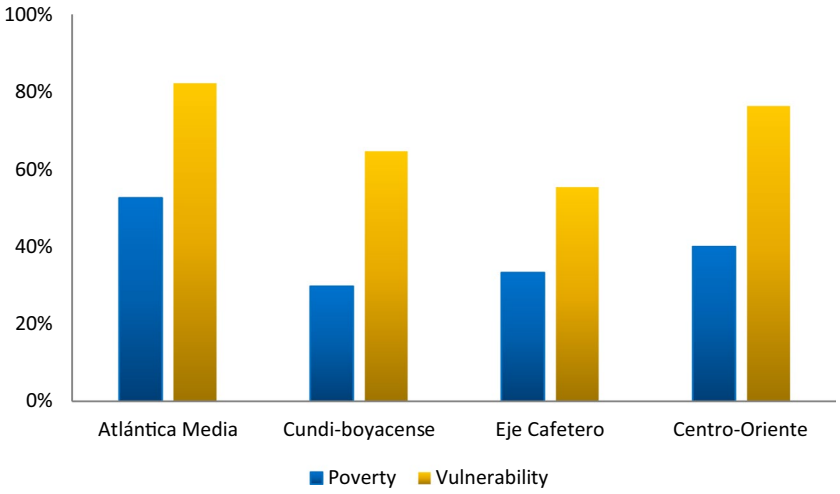

Fig. 4 Household in poverty (MPI) and vulnerability (VEMP) rural area. *Source* ELCA, own elaboration

higher than the poverty observed, which indicates the high degree of volatility of deprivation in these areas. For this reason, a high percentage of households that are not currently poor are at risk of becoming poor in the future. The low levels of vulnerability in the coffee and Cundi-boyacense regions are due to their proximity to the main urban centers. Moreover, the most isolated regions are characterized by frequent political conflict and the presence of illicit crops (Roncancio et al., 2020).

6 Conclusions

In this work, vulnerability is defined as the probability of a person or household becoming poor in the future. Understanding that poverty depends on several dimensions that go beyond income, we analyze the VMP. For this purpose, we employed the FGLS method in three stages using information from the ELCA, which contains data about the shocks faced by households. An intermediate step in this research consisted of measuring multidimensional poverty for the households included in the sample, for which the official index estimated by DANE was adapted to the information available in the ELCA. We also conduct some robustness checks for different poverty lines and different weighting structures to strengthen the MPI calculated in this study.

Concerning our first research question, the results show that the proportion of households that have a high probability of experiencing multidimensional poverty in the future (70% in rural areas and 17% in urban areas) exceeds the population identified as multidimensionally poor (39% in rural areas and 14% in urban areas). This is consistent with the results of previous studies in developing countries about both vulnerability to monetary poverty and the VMP.

One interesting result is that approximately half of the population identified as vulnerable in rural areas is not currently poor (our second research question), which indicates the relevance of designing poverty prevention policies appropriately. Likewise, about 87% of the population identified as poor is vulnerable to future poverty in the rural area. This

result provides evidence of the importance to study the potential existence of poverty traps in Colombia, an interesting issue for a future research agenda.

In view of these results, it is necessary to define appropriate strategies to fight poverty in Colombia. As it could be observed, a significant proportion of population is not currently poor but has a high probability of being poor in the future. Thus, it is essential to consolidate poverty prevention policies, including access to microcredit and the promotion of labor formality. Conversely, a proportion of population requires poverty relief strategies since they are currently poor and vulnerable, i.e. they have a high probability to continue being poor in the future.

As for our third research question, correlations estimated in Table 2 allow us to identify what factors increase or reduce vulnerability to multidimensional poverty. According to the results, female-headed households, self-employment, loss of employment, and bankruptcy of family businesses are factors positively correlated to vulnerability. On the contrary, schooling years, being wage earner and access to credit, reduce vulnerability. These results are aligned with official poverty measures in Colombia, which are higher for women, for individuals with primary education or no schooling, unemployed individuals, and self-employed workers. The evidence reveals the need of improving the social safety net in Colombia, in order to guarantee access to basic social services to the most vulnerable population. It also shows the importance of promoting financial inclusion, since access to credit reduces the risk of remaining in or falling into poverty.

The correlation analysis demonstrated that the dynamics of urban and rural households are different since some household shocks have a different impact in each area. At the urban level, it was found that the Atlantic region deserves special attention since both the percentage of poor and vulnerable households is high (approximately 30%), mainly due to the lack of public service provision. Regarding the rural area, a considerably high level of vulnerability was observed, reflecting a critical situation in rural households in which high MPIs were also estimated. In this line, policies should aim to eliminate the obstacles for rural development, such us extreme inequality in land access, informality in property rights, illegal land appropriation and other types of violence due to the armed conflict.

Finally, this paper can be considered a starting point for future lines of research such as the analysis of poverty traps. In this sense, it is important to point out that the study of poverty and rural vulnerability requires a greater degree of depth, in which other dimensions can be included (e.g., healthcare, child nutrition, perceptions about the peace process, political participation, and clientelism). In addition, future research may focus on remedying some of the criticisms of the VEP approach, for example, the need to incorporate risk sensitivity. In this context, it would be important to analyze the risk of deprivation for different dimensions of poverty, which would serve as an input for estimating the VMP.

Appendix

See Tables 5, 6, 7 and 8.

Table 5 Dimensions and variables of MPI for Colombia

Dimension	Indicator[a]	Deprivation
Educational conditions of households (1/5)	Low educational achievement(1/10)	Head of household and spouse average educational attainment
	Illiteracy (1/10)	Head of household or spouse cannot read and write
Children and youth conditions (1/5)	School absence (1/15)	Less than 100% of children between 6 and 16 years old attend school
	Educational lag (1/15)	Some of the children between 7 and 17 years old are lagging school
	Child labor (1/15)	Less than 100% of children between 12 and 17 years old does not belong to the labor market
Work (1/5)	Long term unemployment (1/10)	For the head of household and spouse, at least one economically active person in long-term unemployment is deprived by this variable
	Informal employment (1/10)	For the head of household and spouse, at least one economically active person has a formal job
Health (1/5)	No health insurance (1/5)	For the head of household and spouse, at least one is not insured in health
Access to public home services and housing conditions (1/5)	No access to improved water source (1/25)	Household does not have connection to the public aqueduct service in the home *Rural Household obtains the water to prepare food from a well without a pump, rainwater, river, spring, public sink, tank car, water carrier or other source
	Inadequate excreta disposal (1/25)	Household does not have a connection to public sewer service *Rural Households with an unconnected toilet, latrine, or low tide, or simply do not have a toilet
	Inadequate floors (1/25)	Household that has dirt floors
	Inadequate exterior walls (1/25)	*Rural The material of the exterior walls of the home is rough wood, board, plank, guadua, another vegetable, zinc, cloth, cardboard, waste or it does not have walls
	Critical overcrowding (1/25)	Number of people per room to sleep excluding kitchen, bathroom and the garage is greater than or equal to 3 *Rural

[a]Weights in parenthesis

Source Own elaboration based on Angulo et al. (2011)

Table 6 Robustness of MPI estimates to different rural weighting structures

		MPI Original	MPI weights 1	MPI weights 2	MPI weights 3	MPI weights 4
MPI weights 1	Pearson	0.9584				
	Spearman	0.9588				
	Kendall (Tau b)	0.9478				
MPI weights 2	Pearson	0.9769	0.9236			
	Spearman	0.9856	0.9336			
	Kendall (Tau b)	0.8322	0.9476			
MPI weights 3	Pearson	0.9582	0.8873	0.9279		
	Spearman	0.9634	0.8958	0.9450		
	Kendall (Tau b)	0.9004	0.7950	0.9402		
MPI weights 4	Pearson	0.9606	0.8865	0.9268	0.9016	
	Spearman	0.9709	0.9057	0.9516	0.9234	
	Kendall (Tau b)	0.8444	0.7363	0.8126	0.9453	
MPI weights 5	Pearson	0.9710	0.9187	0.9422	0.9095	0.9180
	Spearman	0.9781	0.9306	0.9624	0.9310	0.9300
	Kendall (Tau b)	0.8291	0.7323	0.7991	0.7511	0.9362

MPI original = Educational achievement (20%), Children and youth conditions (20%), Work (20%), Health (20%) and housing conditions (20%)

MPI weights 1 = Educational achievement (40%) Children and youth conditions (15%), Work (15%), Health (15%) y and housing conditions (15%)

MPI weights 2 = Educational achievement (15%) Children and youth conditions (40%), Work (15%), Health (15%) y and housing conditions (15%)

MPI weights 3 = Educational achievement (15%) Children and youth conditions (15%), Work (40%), Health (15%) y and housing conditions (15%)

MPI weights 4 = Educational achievement (15%) Children and youth conditions (15%), Work (15%), Health (40%) y and housing conditions (15%)

MPI weights 5 = Educational achievement (15%) Children and youth conditions (15%), Work (15%), Health (15%) y and housing conditions (40%)

Table 7 Robustness of MPI estimates to different urban weighting structures

		MPI Original	MPI weights 1	MPI weights 2	MPI weights 3	MPI weights 4
MPI weights 1	Pearson	0.9622				
	Spearman	0.9598				
	Kendall (Tau b)	0.8099				
MPI weights 2	Pearson	0.9635	0.8986			
	Spearman	0.9622	0.8922			
	Kendall (Tau b)	0.8197	0.7165			
MPI weights 3	Pearson	0.9608	0.8946	0.9064		
	Spearman	0.9662	0.9025	0.9088		
	Kendall (Tau b)	0.8211	0.7253	0.7415		
MPI weights 4	Pearson	0.9705	0.9136	0.9178	0.9182	
	Spearman	0.9630	0.9055	0.9125	0.9205	
	Kendall (Tau b)	0.7804	0.7066	0.7192	0.7214	
MPI weights 5	Pearson	0.9860	0.9449	0.9428	0.9365	0.9546
	Spearman	0.9940	0.9526	0.9544	0.9572	0.9510
	Kendall (Tau b)	0.8603	0.7870	0.7929	0.7914	0.7525

MPI original = Educational achievement (20%), Children and youth conditions (20%), Work (20%), Health (20%) and housing conditions (20%)

MPI weights 1 = Educational achievement (40%) Children and youth conditions (15%), Work (15%), Health (15%) y and housing conditions (15%)

MPI weights 2 = Educational achievement (15%) Children and youth conditions (40%), Work (15%), Health (15%) y and housing conditions (15%)

MPI weights 3 = Educational achievement (15%) Children and youth conditions (15%), Work (40%), Health (15%) y and housing conditions (15%)

MPI weights 4 = Educational achievement (15%) Children and youth conditions (15%), Work (15%), Health (40%) y and housing conditions (15%)

MPI weights 5 = Educational achievement (15%) Children and youth conditions (15%), Work (15%), Health (15%) y and housing conditions (40%)

Table 8 Variables included in the wealth index

Variable description
Access to public services and public infrastructure
Garbage collected by waste disposal services
Water for drinking and preparing food obtained from a public, communal or village aqueduct or well with a pump
Sanitary service: toilet connected to a sewer
Type of energy used for cooking: electric, natural gas connected to a public network or propane (cylinder or pipette)
The house has electricity
The house has telephone service
Characteristics of the house
Suitable flooring material: carpet, marble, parquet, polished wood, tile, vinyl, tablet, or brick
Suitable wall material: block, brick, stone, polished wood, rammed earth, adobe, precast material
Property and use of durable assets
Household owns and uses refrigerator
Household owns and uses washing machine
Household owns and uses shower
Household owns and uses television
Household owns and uses computer
Household owns and uses motorcycle

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