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Multidimensional Poverty in Paraguay: Trends from 2000 to 2015

Paul A. Ervin[1] · Lyliana Gayoso de Ervin[2] · Jose R. Molinas Vega[1,2] · Flavia G. Sacco[2]

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Abstract To meet Paraguay's national development goals and the Sustainable Development Goals, policy makers require more information about poverty in the country. We propose a multidimensional poverty index (MPI) for Paraguay constructed using the Alkire–Foster dual-cutoff method for multidimensional poverty identification to complement existing national poverty measures based on income. Indicators, dimensions, weighting schemes, and cutoffs used in the Paraguayan MPI were determined based on national definitions of poverty and national and international development priorities. The MPI is estimated for the years 2000–2015 using national household surveys. From 2000 to 2015, the multidimensional poverty incidence in Paraguay declined by an average annualized rate of 9.2%, from 58% of the population in 2000 to 17% of the population in 2015. In 2015, 7% of the population is estimated to be living in multidimensional poverty, but not income poverty. This population would have remained invisible based on income poverty measures alone. This is the first MPI proposed for Paraguay that reflects the country's national development priorities. The adoption of the MPI may assist policy makers in targeting previously invisible, vulnerable populations and assessing the impact of public policies on reaching the country's development goals.

Keywords Paraguay · Multidimensional poverty index · Alkire–Foster method · Poverty · Latin America

✉ Paul A. Ervin
paervin@gmail.com

Lyliana Gayoso de Ervin
lyligayoso@gmail.com; lgayoso@stp.gov.py

Jose R. Molinas Vega
jmolinasvega@gmail.com; jmolinasvega@stp.gov.py

Flavia G. Sacco
flaviasaccoc@gmail.com; fsacco@stp.gov.py

[1] Instituto Desarrollo, Guido Spano, 2575 Asunción, Paraguay

[2] Secretaría Técnica de Planificación (STP), Estrella 505 esq. 14 de Mayo, Asunción, Paraguay

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1 Introduction

Despite significant reductions in monetary poverty and inequality in Paraguay over the last decade, reducing poverty in Paraguay remains both a national and an international priority.[1] This is reflected in the Paraguayan National Development Plan 2030 (NDP 2030) (Government of Paraguay 2014), ratified by the Government of Paraguay in 2014, as well as in the United Nations' Sustainable Development Goals (SDG) (United Nations 2015), adopted by Paraguay in 2015. Both development strategies state specific goals to reduce poverty and acknowledge that poverty is not simply the condition of lacking monetary resources, but constitutes numerous factors that influence an individual's experience of deprivations. In this context, the SDGs have the first goal of ending poverty *in all its forms* everywhere, which explicitly acknowledges that poverty is a multidimensional concept.

In order to guide public policies and monitor progress in reducing poverty in all its forms, national definitions of forms, or rather dimensions, of poverty must be defined. Developing public policies to reduce poverty depends largely on the government's ability to identify the poor and the deprivations that they experience. Therefore, not only the dimensions to be monitored need to be defined, but also a number of decisions on aggregating dimensions need to be made. All of these decisions should be made with the objective of creating a multidimensional poverty measure that comprehensively and adequately reflects the deprivations that individuals within society experience.

In this paper, we present a multidimensional poverty index (MPI) for Paraguay. Using data from the annual national household surveys of Paraguay[2] from 2000 to 2015, we apply the Alkire–Foster dual-cutoff methodology to aggregate poverty dimensions and deprivation indicators to create several multidimensional poverty statistics. This methodology satisfies a set of basic axioms for multidimensional poverty measurement and is easily decomposed by geographic regions and population subgroups.

This paper contributes to the literature in several ways. First, it presents the first MPI for Paraguay for the years 2000–2015 created using the latest conceptual and methodological developments in the area of multidimensional poverty. The Paraguayan MPI is rigorously developed based on national and international development priorities. In this sense, the proposed index, given the available data, is fully aligned with the NDP 2030 of Paraguay, as well as with the SDGs. Second, it presents a spatio-temporal analysis of multidimensional poverty in Paraguay, which can assist the government in not only monitoring poverty trends over time from both a multidimensional and monetary perspective, but also with designing geographically tailored policies and assessing the extent to which poverty reduction policies have had the intended effects. Finally, it is hoped that documenting our experience in developing an MPI will provide guidance to researchers and policy makers seeking to develop an MPI in other countries.

In recent years, the concept of multidimensional poverty has gained traction in the field of development. Various methodologies to measure multidimensional poverty have emerged, such as those proposed by Bourguignon and Chakravarty (2003) and Alkire and Foster (2007). In just the last few years there have been substantial advances in methodologies to measure and assess poverty from a multidimensional perspective. In particular, the methodology proposed by Alkire and Foster (2011) has gained wide acceptance, due to

[1] See Lopez-Calva et al. (2015) and national statistics provided by the National Institute of Statistics (DGEEC).

[2] Encuesta Permanente de Hogares (EPH).

its useful axiomatic characteristics. And several countries, such as Mexico, Colombia, Chile, and Costa Rica, among others, have adopted national multidimensional poverty measures as instruments to monitor poverty and to guide development policies.[3]

Several multidimensional poverty indices include Paraguay in regional and global studies of multidimensional poverty. For example, a global MPI is found in Alkire and Santos (2010), UNDP (2010), and Alkire and Santos (2014). A regional MPI for Latin America is presented in Santos et al. (2015). While these studies are informative, the requirement of international comparability limits the indicators that can be included. Indicators important to the Paraguayan national context, such as the high level of employed workers with a salary below the national minimum wage, are often omitted. Other indices, which include Paraguay, focus purely on population subgroups, such as children, and their unique experience of deprivations (Bruno and Osorio 2015). The MPI for Paraguay presented in this document is nationally and regionally representative of the total population and includes a comprehensive set of indicators determined to be highly relevant for national development and public policies.

This paper is organized as follows: Sect. 2 presents the Paraguayan context and the conceptual framework underlying the development of the Paraguayan MPI, Sect. 3 describes the methodology, discusses data sources and data limitations, and presents the selected dimensions, indicators, and weights used to construct the MPI, as well as robustness tests. Finally, Sect. 4 discusses the main results, and Sect. 5 concludes.

2 Paraguayan Context and Conceptual Framework

Paraguay is a landlocked country located near the Southern Cone region in South America. The country is home to the largest rural population in South America with approximately 40% of its population of 6.6 million residing in rural areas (World Bank 2016).[4] The Paraguayan economy is dominated by the agricultural sector, which accounts for approximately 20% of the country's gross domestic product (GDP) (BCP 2017). Despite its relatively small population, Paraguay is the sixth largest producer of soy and the eighth largest exporter of beef in the world (FAO 2017).

From 2006 to 2015, Paraguay's real GDP per capita growth was one of the highest in South America, averaging 3.4% year-over-year. Although economic growth has been relatively stable in recent years, the country had one of the most volatile economies in Latin America between 2001 and 2011, due to the reliance of its economy on select crops and export markets in the agriculture sector (Koehler-Geib et al. 2014). Although the service industry is growing, most people work in agriculture and the majority of workers are either self-employed or unpaid family workers (DGEEC 2015). The country's large rural population, reliance on agriculture, and large informal labor sector, present a number of development challenges in terms of creating infrastructure, providing access to goods and services, and ensuring employment security.

[3] Mexico was the first country to adopt an MPI. Information about their experience can be found in http://www.coneval.org.mx/Paginas/principal.aspx, and CONEVAL (Consejo Nacional de Evaluación de la Política de Desarrollo Social de México) (2010). See Angulo et al. (2016) for an MPI for Colombia, Ministerio de Desarrollo Social de Chile (2015) for an MPI for Chile, and INEC (2015) for the Costa Rican experience, among others.

[4] This is followed by Ecuador and Bolivia with 36 and 31% of the population residing in rural areas, respectively.

The Paraguayan National Development Plan 2030 (NDP 2030) coordinates the country's national development goals across sectors and defines specific targets in infrastructure, access to goods and services, and employment, as well as other areas, to be reached by the year 2030 (Government of Paraguay 2014). After adopting the NDP 2030 in 2014, Paraguay agreed on the United Nations' Sustainable Development Goals (SDGs) in 2015. The SDGs define the country's international development priorities and overlap significantly with the NDP 2030 national development goals (United Nations 2015). Both the NDP 2030 and SDGs reinforce Paraguay's commitment to the eradication of extreme poverty, based on income definitions of poverty, and put forth specific goals to create infrastructure, ensure equal access to basic goods, services, and quality employment, as well as to improve governance and the environment.

The SDGs extend the country's commitment from reducing monetary poverty to reducing poverty in all of its forms based on national definitions of poverty dimensions. This poses a challenge to the country, because national dimensions of poverty have yet to be explicitly defined. Currently, a process is underway in Paraguay to develop national definitions of multidimensional poverty, to which this paper seeks to contribute.

Two common approaches for determining the dimensions of multidimensional poverty are the basic needs and the capabilities approach.[5] The basic needs approach is based on the idea that there exists basic goods and services, such as water, shelter, and sanitation, that are necessary for the full development of an individual (Streeten 1979). This approach has a long history as a framework for multidimensional poverty measurement in Latin America, due to the development stage of the region and data availability (Santos 2014; Santos et al. 2015). The capabilities approach, most notably championed by Sen (1992), argues that improving people's capabilities will enhance their well-being by providing them the freedom and capability to lead their own lives. In the capabilities approach, dimensions of poverty are functionings that individuals are able to achieve, such as literacy and having a good job.

To determine the poverty dimensions in the Paraguayan multidimensional poverty index, we adopt a conceptual framework aligned with both the capabilities approach and the basic needs approach. The decision to mix these two approaches facilitates the development of a Paraguayan multidimensional poverty index that incorporates both national development goals from the NDP 2030 and international development goals from the SDGs. In this way, the Paraguayan multidimensional poverty index can be used to not only monitor multidimensional poverty, but progress on national and international development priorities, more generally.

3 Methods and Data

We begin this section by introducing the methodology used to construct the Paraguayan MPI. This is followed by a discussion of data availability. We then introduce the structure of the Paraguayan MPI along with several robustness analyses.

[5] Alternative approaches are rapidly growing. See Kakwani and Silber (2008), for a further discussion on dimensions of poverty.

3.1 Methodology

The MPI for Paraguay is constructed using the dual-cutoff methodology proposed by Alkire and Foster (2011). It is based on the adjusted headcount ratio, the M_0 measure of multidimensional poverty, which combines measures of both multidimensional poverty incidence and multidimensional poverty intensity. The aggregation method for the MPI is briefly described in this section. We note that the MPI can be constructed in a number of different, but equivalent ways. For further details on constructing an MPI and on additional measures in the Alkire–Foster class of poverty measures, we direct the reader to Alkire et al. (2015a, chapter 5).

The dual-cutoff methodology involves two steps to identify individuals living in multidimensional poverty. In the first step we construct individual deprivation profiles and in the second step we determine whether an individual is in multidimensional poverty based on his or her deprivation profile. To construct deprivation profiles, we begin by determining a set of achievement indicators, x_{ij}, for individuals $i = 1, \ldots, n$ and indicators $j = 1, \ldots, d$ and deprivation cutoffs z_j for each indicator j. A person is considered deprived in achievement indicator j if her (or her household's) achievement is below the deprivation cutoff z_j. We define uncensored deprivation indicators as,

$$g_{ij}^0 = I(x_{ij} < z_j), \tag{3.1}$$

for each individual i and indicator j, where $I(\cdot)$ is an indicator function whose value equals 1 if the argument in the brackets is true, and 0 if the argument in the brackets is false. A deprivation score c_i is then computed for each individual i as the weighted sum of uncensored deprivation indicators. That is, $c_i = \sum_{j=1}^{d} w_j g_{ij}^0$, where w_j is the predetermined standardized weight corresponding to indicator j, such that $\sum_{j=1}^{d} w_j = 1$ and $w_j \in [0, 1]$.

Given the deprivation score c_i, we can now construct a multidimensional poverty indicator $\rho_k(x_{i\cdot}; z) = I(c_i \geq k)$ for each individual i. Because $I(\cdot)$ is an indicator function, $\rho_k(x_{i\cdot}; z)$ identifies an individual i as multidimensional poor when her deprivation score is greater than or equal to the predetermined multidimensional poverty cutoff, k. If an individual has a deprivation score c_i lower than k, then she is not poor according to $\rho_k(x_{i\cdot}; z)$. We note that because $\rho_k(x_{i\cdot}; z)$ depends on both the set of within-dimension deprivation cutoffs z_j and the across-dimension cutoff k, $\rho_k(x_{i\cdot}; z)$ is referred to as the dual-cutoff method of multidimensional poverty identification (Alkire et al. 2015a, chapter 5).

The unadjusted multidimensional poverty headcount ratio, or incidence, H, is calculated as,

$$H = \frac{1}{n} \sum_{i=1}^{n} \rho_k(x_{i\cdot}; z) = \frac{q}{n}. \tag{3.2}$$

Note that $\sum_{i=1}^{n} \rho_k(x_{i\cdot}; z)$ is equal to the total number of individuals identified as multidimensional poor, which we have defined as q above.

Next we define censored deprivation indicators as,

$$g_{ij}^0(k) = g_{ij}^0 \cdot \rho_k(x_{i\cdot}; z), \tag{3.3}$$

for each individual i and indicator j. Formally, multiplying a deprivation indicator g_{ij}^0 by the multidimensional poverty indicator $\rho_k(x_{i\cdot}; z)$ censors the deprivation indicator of a non-poor individual to zero. The censored deprivation score is then calculated as

$c_i(k) = \sum_{j=1}^{d} w_j g_{ij}^0(k)$, which is the weighted sum of the censored deprivation indicators. Finally, we calculate the multidimensional poverty intensity as

$$A = \frac{1}{q}\sum_{i=1}^{n} c_i(k), \tag{3.4}$$

which is the average deprivations among the individuals identified as multidimensional poor.

The MPI for Paraguay, which is created using the adjusted headcount ratio, M_0, is the product of the multidimensional poverty headcount ratio H and the multidimensional poverty intensity A. Formally,

$$MPI = M_0 = H \cdot A = \left[\frac{q}{n}\right] \cdot \left[\frac{1}{q}\sum_{i=1}^{n} c_i(k)\right] = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{d} w_j g_{ij}^0(k). \tag{3.5}$$

The MPI for Paraguay satisfies a set of basic axioms for multidimensional poverty measurements (Alkire and Foster 2011). For example, because the headcount ratio is adjusted by the multidimensional poverty intensity A, it satisfies dimensional monotonicity. This means that the MPI would increase if an already poor individual became deprived in an additional indicator.

Lastly, the MPI can easily be decomposed into the contributions of each indicator or dimension. Rewriting the MPI as

$$MPI = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{d} w_j g_{ij}^0(k) = \sum_{j=1}^{d} w_j \left[\frac{1}{n}\sum_{i=1}^{n} g_{ij}^0(k)\right] = \sum_{j=1}^{d} w_j h_j(k), \tag{3.6}$$

where $h_j(k)$ is the censored headcount ratio of deprivation indicator (or dimension) j, the contribution of a deprivation indicator to the overall MPI can be expressed as,

$$\phi_j^0(k) = w_j \cdot \frac{h_j(k)}{MPI}, \tag{3.7}$$

which depends on both the weight assigned to a deprivation indicator j, w_j, and its censored headcount ratio, $h_j(k)$. If the contribution of an individual deprivation indicator exceeds the weight assigned to it, then the censored headcount ratio in this dimension must be relatively high. That is, the poor must be more deprived in this deprivation dimension than in others (Alkire et al. 2015a, chapter 5).

Finally, since data from national household surveys are drawn using a bi-stage stratified random sampling design, following department (state) urban/rural stratification with survey blocks as the primary sampling units and households within the blocks as the secondary sampling units, we calculate all multidimensional poverty statistics and confidence intervals incorporating sample weights and survey design.[6]

3.2 Data

In this section, we discuss the data that are available in Paraguay to create an MPI and several limitations of the data.

[6] Robust standard errors are calculated allowing for arbitrary forms of heteroskedasticity within a primary sampling unit.

3.2.1 Data Sources

A key requirement of the data used in constructing an MPI is that each indicator is available within the same survey and linked at the individual or household level. This ensures that the constructed MPI is a measure of the joint deprivations experienced by individuals or households living in multidimensional poverty (Alkire and Foster 2011). A number of data sources are available in Paraguay that could potentially be used to create an MPI. However, only the annual national household survey, known as the Encuesta Permanente de Hogares (DGEEC 2000–2015), and referred to as the EPH throughout this document, provides adequate data to create a comprehensive MPI that can be monitored annually at various geographic levels.[7]

The MPI for Paraguay is created using data drawn from the EPH for the years 2000–2015. Although the survey has been conducted annually since 1997, we restricted our sample to the survey rounds presented in Table 1 based on several data limitations discussed in the following subsection. The EPH is a nationally and regionally representative survey administered annually since 1997 by the Paraguayan National Statistical Office (Dirección General de Estadísticas, Encuestas y Censos).[8] The EPH contains modules on household demographics, household amenities, assets, land, and livestock ownership. Consequently, a comprehensive MPI for Paraguay can be calculated using data from these surveys. Additionally, given the geographic representativeness of the surveys, once an MPI is constructed, it is possible to decompose the MPI by the following geographic levels: departments and urban and rural areas.

3.2.2 Data Limitations

The EPH in Paraguay appears to provide high quality information.[9] Nevertheless, the survey instruments, questions, and available response categories often change from survey to survey. Changes occurred more often in the first 5 years of the survey with smaller survey changes occurring after this period. In the case of survey changes, exhaustive efforts were made to match survey questions with the most suitable questions in the following years. Additionally, the survey rounds for the years 1997, 1999, 2002, and 2011 omitted several key questions necessary to calculate indicators in the MPI.[10] These years were omitted from our analysis, so that the MPI is comparable across all years where data are

[7] Other potential sources of data are the "Encuesta Continua de Empleo" (ECE), 2002 and 2012 Censuses, and the "Encuesta de Ingresos y Gastos y Condiciones de Vida 2011/2012" (EIGyCV) (DGEEC 2010, 2011). The ECE is only representative of Asunción and urban Central, and provides limited data to monitor an adequate set of indicators of an individual's experience of deprivations. The census would allow the exploration of the MPI at a very fine geographic level, but it too provides limited data to monitor an individual's experience of deprivations. An additional shortcoming of censuses are that they are typically undertaken every 10 years and, thus, provide limited opportunities for continuous monitoring. The EIGyCV provides more information than the EPH that could be useful for the MPI, such as child's health and nutrition, subjective well-being, trust in government institutions, and corruption, but it is also not suitable for monitoring multidimensional poverty, because it is only available for 1 year.

[8] While the survey has been conducted annually, there have been some exceptions at the beginning of the survey. For example, the 1997 survey was undertaken between 1997 and 1998. Similarly, the 2000 survey was conducted between 2000 and 2001.

[9] Judge and Schechter (2009) investigated data quality of several national household surveys, which included the EPH, and suggested data from the EPH are good quality.

[10] This was the case for health insurance, sickness and accidents, television ownership, and internet access.

Table 1 EPH sample size per year

Year	No. of households	No. of people
2000/01[a]	8131	37,437
2003[a]	9591	43,161
2004[a]	7823	34,636
2005	4464	19,579
2006	5292	22,733
2007	4812	21,053
2008	4601	19,416
2009	4439	18,419
2012	5288	21,151
2013	5424	21,207
2014	5165	20,272
2015[a]	8299	30,898

[a]Surveys that were conducted with a larger sample size to expand geographic representation

available. A very low percentage of missing data remained in our restricted sample and was subsequently omitted from the analysis.[11]

A main limitation of the data was availability. The NDP 2030 and the SDGs place a strong emphasis on nutrition, health, environmental sustainability, and human rights. In the case of Paraguay, however, data on nutrition is only available in the household surveys for few years, and future collection of these data is uncertain. Thus, nutrition could not be included in the MPI. Additionally, the household surveys currently collect limited information on health, environment, and human rights. And while the data include information on general access to goods and services, information about the quality of these goods and services is lacking. As data becomes available in these areas in the future, the comprehensiveness of the Paraguayan MPI may be improved with additional dimensions and indicators.

Finally, all survey rounds are only representative of the following geographic areas: five departments, the capital city of Asunción, and an additional category that groups the remaining ten departments. Only few survey rounds are representative of fifteen of Paraguay's seventeen departments and the capital city, such as the 2015 survey round. Two departments, Boquerón and Alto Paraguay, which represent less than 2% of Paraguay's population, are never surveyed.

3.3 Structure of the Paraguayan Multidimensional Poverty Index

We now present the dimensions, indicators, and deprivation cutoffs used in the Paraguayan MPI and discuss the parsimony of the MPI. This is followed by a presentation of the weighting structure and multidimensional poverty cutoff used to construct the MPI. Finally, we perform a robustness analysis on key parameters.

3.3.1 Dimensions, Indicators, and Deprivation Cutoffs

The MPI for Paraguay proposed in this paper is based on the country's policy commitments, data availability, and a consultative process with the country's Inter-institutional

[11] Table 5 in the appendix presents the share of missing values by indicator.

Committee on Poverty Measurement. The capabilities approach and the basic needs approach provide the conceptual framework, in line with recent work of Alkire and Foster (2011), Alkire and Santos (2010, 2014), and others. All development priorities and policies according to the NDP 2030 and the SDGs were considered, so that the MPIs dimensions and indicators would be able to reflect development progress and could be used to monitor the impact of policies on reducing multidimensional poverty.

The MPI for Paraguay seeks to take advantage of the available information in the 2000–2015 survey rounds of the EPH, while considering at the same time normative judgments on what it means to live in poverty in Paraguay. To this end, all potential dimensions and indicators were presented and discussed with the National Inter-institutional Committee on Poverty Measurement. This committee, initially active from 2008 to 2009, reconvened in 2014, and includes key experts on poverty from public offices, civil society, international agencies, the private sector, and academia. Lastly, considerations were made based on annual national reports on living standards, known as "Condiciones de Vida de la Población Paraguaya" in Spanish, which characterize the living standards of Paraguayans in terms of housing quality, access to basic services, and asset ownership among other things (DGEEC 2002a).

The following strategy was used to determine which indicators to include in the MPI to capture poverty in Paraguay. First, we performed a thorough literature review of existing multidimensional poverty indices and their components, to ensure we capture the state of the art in empirically operationalizing the capability and basic needs approaches.[12] Second, we compiled a complete list of indicators based on the extant literature, the national report on living conditions, the national development priorities described in Paraguay's NDP 2030, and the SDGs, constrained by data availability in the EPH. Implicit in this strategy is a definition of poverty determined by stated national development priorities, in which all deprivation indicators contained in the proposed MPI for Paraguay are normatively justified based on the existing literature, and national development priorities. Additional considerations about the indicators included in the MPI were based on a number of descriptive analyses, such as redundancy analysis and robustness analysis, which are presented in Sect. 4.

All indicators included in the MPI are defined at the household level and assume equal distribution and externalities within the household. In this way, the unit of identification for the MPI is the household and all members of the same household are considered poor if the household has been identified as multidimensionally poor. A household is defined as "the single person or groups of persons, whether or not they are relatives, who habitually reside in a particular dwelling, occupy it totally or partially and who attend to their food needs in common" following the definition of a household proposed by the national statistical office, (DGEEC 2002b). Nevertheless, the unit of analysis is the individual. That is, all household members, and thus the population, are considered when aggregating data to calculate multidimensional poverty statistics. The use of the household as a unit of identification supports public policies that are typically targeted to households.

As a final result of this work, 20 indicators grouped into 4 dimensions were selected for the Paraguayan MPI. The following dimensions are included in the MPI: (1) Health, Water,

[12] For reviews of multidimensional poverty in Latin America see Santos (2014), CEPAL (2013). For an MPI for the Latin America region see Santos et al. (2015). For global MPIs see Alkire and Santos (2010, 2014), UNDP (2010). For country specific MPIs see CONEVAL (Consejo Nacional de Evaluación de la Política de Desarrollo Social de México) (2010) for Mexico, Angulo et al. (2016) for Colombia, and Ministerio de Desarrollo Social de Chile (2015) for Chile. For more studies on multidimensional poverty, we recommend visiting the OPHI website at http://www.ophi.org.uk/.

and Sanitation, to capture the ability to lead a healthy life; (2) Housing and Basic Goods and Services, displaying the ability to lead a life with dignified housing conditions and connectivity to others; (3) Education, related to the ability to lead a life with adequate learning conditions; and (4) Employment, displaying the ability to deploy owns labor force adequately. The definitions of dimensions and deprivation indicators for the Paraguayan MPI are shown in Table 2. All these indicators are closely related to the priorities of the NDP 2030 and the SDGs. In the rest of this section, we describe the deprivation indicators included in each dimension of the MPI.

Health, Water, and Sanitation For the selection of indicators in this dimension we consider key elements related to the ability to lead a healthy life. First, *water source*, seeks to capture an individual's deprivation in terms of access to drinking water inside the house or the property. The second indicator in this dimension is *water supply*. Considering the national definition of advanced water supply from the living standards report of Paraguay, an individual is deprived if the household cannot obtain water from a safe supplier (DGEEC 2002b). The third indicator included in this dimension is *sanitation*, which is meant to capture whether an individual has access to an advanced drainage system, also following definitions in the national living standards report (DGEEC 2002b).

The *kitchen and cooking fuel* indicator measures whether household members cook in potentially unhealthy conditions, for instance when using cooking fuels that cause high levels of air pollution. Members of a household are deprived in this indicator if they do not have a kitchen and they cook with wood or coal. Finally, the *healthcare* indicator captures whether members of a household have access to medical services. All members of a household are considered deprived if any sick or injured household member did not seek medical treatment due to a self-reported lack of financial resources or poor quality of local medical care. Household members who did not seek treatment, because they believed their illness or injury was not severe were not considered deprived.

Housing and Basic Goods and Services This dimension seeks to capture the challenges to lead a life with dignified housing conditions and connectivity to others, and it is composed of six indicators. First, for the *housing materials* indicator, we follow the classification of housing in the national report on living standards to define deprivation (DGEEC 2002b). We defined deprivation in this indicator if the materials used to build the walls, roof, and floor are considered low quality materials, such as dirt, cardboard, straw, and mud. Second, the indicator *persons per room* is meant to capture whether household members are living in an overcrowded house. Following Santos et al. (2015), we define that an individual is deprived if the number of people per room in her household is three or greater. Additionally, members of a household are consider deprived if they do not have access to *electricity*. The next indicator, *durable goods*, suggests an individual is deprived in this indicator if her household does not own a car and does not own two or more of the following goods: motorcycle, washing machine, or refrigerator. In the case of *telephone*, this indicator seeks to capture whether an individual has access to any form of telephone communication, such as a land line connection or cellphone. Finally the indicator *access to information* captures whether an individual has access to information either through internet or TV with cable or antenna. The rationale behind this indicator is that household members can access information, such as news and market reports, with a TV, so long as it has a cable or an antenna connection, or through any device with internet connection. Thus, deprivation is this indicator implies that an individual does not have access to internet or to a TV with a cable connection or antenna.

Table 2 Dimensions, deprivation indicators, and weights

Dimensions[a]	Deprivation indicator: individual is deprived if...	Weights
Health, water, and sanitation		0.250
Water source	Household does not have access to piped drinking water inside the house or on the property	0.050
Water supply	Household does not receive drinking water from public utilities, a community or private network, or artesian well	0.050
Sanitation	Household does not have a toilette connected to sewage system, septic tank or well	0.050
Kitchen and cooking fuel	Household does not have a kitchen and cooks with wood or coal	0.050
Healthcare	Any sick or injured household member did not seek medical treatment due to lack of resources or the quality of medical care available	0.050
Housing and basic goods and services		0.250
Housing materials	Household uses dirt, cardboard, straw, mud or other precarious materials for the roof, wall, or floor	0.0417
People per room	Household has three or more people per bedroom	0.0417
Durable goods	Household does not own a car and does not own two or more of the following goods: motorcycle, washing machine, or refrigerator	0.0417
Electricity	Household does not have electricity	0.0417
Telephone	Household does not have a cell phone or land line	0.0417
Access to information	Household does not have internet or a TV with cable or antenna	0.0417
Education		0.250
Delayed education	Household has at least one member (6–20 years old) with less than 12 years of schooling, who is currently enrolled in school and is 2 years delayed with respect to their schooling grade for age	0.050
Child enrollment	Household has at least one member of mandatory schooling age (6–14 years old), who is not currently enrolled in school	0.050
Schooling achievement	Household has at least one adult member that did not complete mandatory schooling, defined as the following: 9 years of schooling for people between the ages of 20 and 33, and 6 years of schooling for people over the age of 33	0.050
Literacy	Household has at least one member (15 years or older), who is illiterate	0.050
Early dropout	Household has at least one member (15–17 years old), who is not attending school	0.050
Employment		0.250
Under- or unemployed	Household head or spouse (partner) is unemployed or underemployed (works 30 h a week or less and wants to work more)	0.0625
Salary	Household head or spouse (partner) works 30 h or more a week, but earns less than the minimum wage	0.0625
Child labor	Household has at least one child (10–14 years old), who is active in the labor market	0.0625
Work or study	Household has at least one young adult (15–19 years old), who neither works nor attends school	0.0625

Education This dimension is meant to capture the household's difficulties with the ability to lead a life with adequate learning conditions and is composed of five indicators. The first indicator, *delayed education*, captures whether household members who haven't completed at least 12 years of schooling, but are currently enrolled in school, are behind in their corresponding grades by 2 or more years based on their age. In this context, members of a household are considered deprived in this indicator if at least one household member is currently enrolled in school and is behind in school by at least 2 years. The second indicator in this dimension refers to *child enrollment*. In Paraguay, child enrollment is mandatory at 6 years of age, and 9 years of compulsory schooling are required. Thus, if a household has any school-age members between 6 and 14 years-old that are not attending school as required, then all members of that household are deprived in this indicator.

Regarding *schooling achievement*, members of a household are considered to be deprived in this indicator if the household has at least one adult member (20 years old and more) that did not complete compulsory schooling. It is important to note that education was reformed in 1994 and compulsory schooling increased from 6 to 9 years. Therefore, compulsory schooling years are considered to be 6 years for cohorts before the reform, and 9 years for cohorts after the reform.

The next indicator in this dimension is *literacy*. An individual is considered deprived in this indicator if any household member over 15 years of age cannot read or write. The final indicator in this dimension is *early dropout*. This captures the population between 15 and 17 years old that is not attending school. Hence, members of a household are deprived if at least one member of the household in this age range is not attending school. It is important to note that members of a household are not considered deprived in any indicator that considers school-age population if the household does not have school-age children.

Employment This dimension seeks to provide information on the challenges that household members face regarding their ability to deploy their labor force adequately through four indicators. *Under- or unemployed*, seeks to capture the working conditions of the household head or spouse (partner). Therefore, members of a household are considered deprived if the household head or spouse (partner) is unemployed or underemployed (works 30 h a week or less and wants to work more). Note that household members are considered non-deprived if both the household head and spouse (partner) are inactive in the labor market, i.e. neither wish to work, nor are actively seeking employment. The next indicator in this dimension is *salary*. This indicator captures whether the household head or spouse (partner) works 30 h or more per week, but earn less than the minimum wage.

The third indicator in this dimension is *child labor*. Members of a household are deprived if the household has at least one child (between 10 and 14 years old)[13] that is working or is active in the labor market. Finally, the indicator *work or study* seeks to capture the youth population that neither works nor studies. This indicator was included from a normative perspective, due to the high risk of limited future prospects for this population. Members of a household are considered deprived in this indicator if the household has at least one member between the ages of 15 and 19 years that is neither working nor studying. Note that individuals in households without members in this age range are not considered deprived in this indicator.

Descriptive statistics for all the deprivation indicators included in the MPI for select years are found in Table 3. Since each deprivation indicator is an indicator variable equal

[13] Unfortunately the EPH does not provide information on work conditions for children younger than 10.

Table 3 Means and standard deviations for select years

Dimensions and deprivation indicator	Years			
	2000	2005	2010	2015
Health, water, and sanitation				
Water source	0.538	0.275	0.226	0.238
	(0.50)	(0.45)	(0.42)	(0.43)
Water supply	0.478	0.369	0.292	0.314
	(0.50)	(0.48)	(0.45)	(0.46)
Sanitation	0.479	0.382	0.310	0.188
	(0.50)	(0.49)	(0.46)	(0.39)
Kitchen	0.113	0.074	0.083	0.035
	(0.32)	(0.26)	(0.28)	(0.18)
Healthcare	0.161	0.078	0.022	0.007
	(0.37)	(0.27)	(0.15)	(0.09)
Housing and basic goods and services				
Housing materials	0.252	0.189	0.177	0.108
	(0.43)	(0.39)	(0.38)	(0.31)
People per room	0.416	0.332	0.286	0.223
	(0.49)	(0.47)	(0.45)	(0.42)
Durable goods	0.521	0.460	0.288	0.130
	(0.50)	(0.50)	(0.45)	(0.34)
Electricity	0.095	0.056	0.024	0.005
	(0.29)	(0.23)	(0.15)	(0.07)
Telephone	0.624	0.450	0.104	0.024
	(0.48)	(0.50)	(0.31)	(0.15)
Access to information	0.967	0.834	0.757	0.477
	(0.18)	(0.37)	(0.43)	(0.50)
Education				
Delayed education	0.334	0.302	0.243	0.155
	(0.47)	(0.46)	(0.43)	(0.36)
Child enrollment	0.105	0.080	0.044	0.024
	(0.31)	(0.27)	(0.20)	(0.15)
Schooling achievement	0.711	0.621	0.563	0.465
	(0.45)	(0.49)	(0.50)	(0.50)
Literacy	0.228	0.200	0.151	0.117
	(0.42)	(0.40)	(0.36)	(0.32)
Early dropout	0.154	0.113	0.103	0.069
	(0.36)	(0.32)	(0.30)	(0.25)
Employment				
Under- or unemployed	0.145	0.122	0.107	0.110
	(0.35)	(0.33)	(0.31)	(0.31)
Salary	0.140	0.188	0.177	0.182
	(0.35)	(0.39)	(0.38)	(0.39)
Child labor	0.118	0.112	0.087	0.042
	(0.32)	(0.32)	(0.28)	(0.20)

Table 3 continued

Dimensions and deprivation indicator	Years			
	2000	2005	2010	2015
Work or study	0.171	0.148	0.132	0.103
	(0.38)	(0.36)	(0.34)	(0.30)

Standard deviations are reported in parentheses

to one if an individual is deprived and a zero otherwise, the means in Table 3 are the proportion of the population deprived in each indicator. Descriptive statistics for the complete set of years included in this study can be found in Table 6 in the appendix.

3.3.2 *Parsimony*

Parsimony means that we seek to develop an MPI that includes only the deprivation indicators and parameters necessary to create a comprehensive index. Clearly, there is a tradeoff between parsimony and comprehensiveness (Santos and Santos 2014). We anticipate that as the MPI includes additional deprivation indicators, potential redundancies and overlap between indicators could emerge.

To investigate potential overlap and redundancies in deprivation indicators, we compute statistics of correlation and redundancy between deprivation indicators within dimensions. The two statistics we calculate were suggested by Alkire et al (2015a, chapter 7). The first statistic is the Cramér's **V** correlation coefficient, henceforth referred to as Cramér's **V**. Cramér's **V** is calculated using the information from cross-tabulations of any two indicators, j and j', such that,

$$\text{Cramér's } \mathbf{V} = \frac{\left(\mathbb{P}^{jj'}_{00} \cdot \mathbb{P}^{jj'}_{11}\right) - \left(\mathbb{P}^{jj'}_{10} \cdot \mathbb{P}^{jj'}_{01}\right)}{\left(\mathbb{P}^{j'}_{+1} \cdot \mathbb{P}^{j}_{1+} \cdot \mathbb{P}^{j'}_{+0} \cdot \mathbb{P}^{j}_{0+}\right)^{1/2}}, \tag{3.8}$$

where in the numerator, $\mathbb{P}^{jj'}_{00}$ is the proportion of people not deprived in both deprivation indicators j and j', $\mathbb{P}^{jj'}_{11}$ is the proportion of people deprived in both deprivation indicators j and j', $\mathbb{P}^{jj'}_{10}$ is the proportion of people deprived in deprivation indicator j but not in j', $\mathbb{P}^{jj'}_{01}$ is the proportion of people not deprived in deprivation indicator j but deprived in j'. In the denominator $\mathbb{P}^{j'}_{+1}$ and $\mathbb{P}^{j}_{1+}$ are the proportions of people deprived in deprivation indicator j' and j, respectively, and $\mathbb{P}^{j'}_{+0}$ and $\mathbb{P}^{j}_{0+}$ are the proportions of people not deprived in deprivation indicator j' and j, respectively.

The second statistic we calculate is a measure of redundancy or overlap referred to as $\mathbf{R^0}$. Using the same notation as Eq. (3.8) above $\mathbf{R^0}$ is defined as,

$$\mathbf{R^0} = \mathbb{P}^{jj'}_{11} / \min\left(\mathbb{P}^{j'}_{+1}, \mathbb{P}^{j}_{1+}\right), \tag{3.9}$$

$\mathbf{R^0}$ is, therefore, the proportion of people deprived in a single deprivation indicator j or j', whichever is smaller, that are jointly deprived in both deprivation indicators j and j'. The minimum of the marginal deprivation rate for deprivation indicator j and j' is used in the

denominator to ensure a maximum value of 1.[14] Because the denominator is always some positive proportion, $\mathbf{R^0}$ will always be defined and take a value between 0 and 1.

To better understand how $\mathbf{R^0}$ provides a measure of redundancy, consider an example where $\mathbf{R^0} = 0.80$. In this case 80% of people deprived in deprivation indicator j, assuming deprivation indicator j has the lower deprivation rate compared to j', are jointly deprived in deprivation indicator j', i.e. 4 of 5 people deprived in one indicator are deprived in the other. Thus, $\mathbf{R^0}$ may provide a more direct measure of the degree of overlap of deprivations than the Cramér's **V** correlation coefficient, because it depends solely on the degree of overlap in deprivations within deprivation indicators. Cramér's **V** correlation coefficients and $\mathbf{R^0}$ redundancy measures for deprivation indicators within dimensions are presented in Table 4.

The largest values of Cramér's **V**, with values ranging from 0.67 to 0.37, are found between the following deprivation indicators, which are listed in descending order: water source and water supply; durable goods and telephone; water source and sanitation; housing materials and durable goods; durable goods and access to information; and schooling achievement and literacy. Within this group of indicators, and amongst all indicators, the deprivation indicators schooling achievement and literacy have the highest $\mathbf{R^0}$ with a value of 0.98. This implies that 98% of the individuals deprived in the literacy deprivation indicator are also deprived in schooling achievement.

Other large values of $\mathbf{R^0}$ greater than 0.80 are found between the following deprivation indicators, again listed in descending order: electricity and access to information; schooling achievement and literacy; durable goods and electricity; housing materials and access to information; durable goods and access to information; telephone and access to information; people per room and access to information; electricity and telephone; child enrollment and schooling achievement; water source and water supply. Here an $\mathbf{R^0}$ greater or equal to 0.80 is considered large, so that 4 of every 5 people deprived in one deprivation indicator are jointly deprived in the other deprivation indicator.

The results of Cramér's **V** and $\mathbf{R^0}$ offer several insights. First, of the ten $\mathbf{R^0}$ values above 0.8, seven are found in the housing and access to basic goods and services dimension. Within this dimension, deprivations in access to information and electricity have a large amount of overlap with deprivation in other indicators. This finding is not surprising, given that electricity is necessary to operate many of the goods and services that are components of other deprivation indicators, such as telephones, televisions, washing machines, refrigerators, and internet. Second, of the remaining four $\mathbf{R^0}$ values above 0.8, two are found in the education dimension. Again this finding is not surprising, because it is well known that illiterate adults likely did not complete a high level of education, and that parents (adults) with low levels of education, on average, demand less education for their children. Finally, the final $\mathbf{R^0}$ value greater than 0.8 comes from water source and water supply, because receiving water from a certain supply, such as public utilities, private or community networks, or artesian wells, often implies having piped water within the house or property.

The results found in this section served the basis for a number of discussions on the selection of indicators for the MPI. Combining indicators, such as schooling achievement with literacy and water supply with water source, and dropping indicators, such as electricity, were considered. Ultimately, it was decided to include all indicators separately for

[14] This formulation of $\mathbf{R^0}$ was first introduced by Simpson (1943). For further information on this measure see Alkire (2012).

Table 4 Cramér's V and redundancy measure $\mathbf{R^0}$

Within dimension	Deprivation indicators	V	R^0
Health, water, and sanitation	Water source and water supply	0.6745	0.8171
	Water source and sanitation	0.4263	0.6908
	Water source and kitchen and cooking fuel	0.1201	0.5652
	Water source and healthcare	0.1430	0.5990
	Water supply and sanitation	0.3109	0.5831
	Water supply and kitchen and cooking fuel	0.0059	0.4308
	Water supply and healthcare	0.1049	0.5856
	Sanitation and kitchen and cooking fuel	0.1727	0.6822
	Sanitation and healthcare	0.1884	0.7047
	Kitchen and cooking fuel and healthcare	0.0607	0.1326
Housing and basic goods and services	Housing materials and people per room	0.3123	0.4815
	Housing materials and durable goods	0.3925	0.7857
	Housing materials and electricity	0.2790	0.7280
	Housing materials and telephone	0.3086	0.6351
	Housing materials and access to information	0.2461	0.9726
	People per room and durable goods	0.3030	0.5920
	People per room and electricity	0.1595	0.5052
	People per room and telephone	0.2259	0.4805
	People per room and access to information	0.2344	0.8918
	Durable goods and electricity	0.2586	0.9756
	Durable goods and telephone	0.4645	0.7400
	Durable goods and access to information	0.3720	0.9620
	Electricity and telephone	0.2575	0.8860
	Electricity and access to information	0.1155	0.9992
	Telephone and access to information	0.2886	0.9563
Education	Delayed education and child enrollment	0.1202	0.3743
	Delayed education and schooling achievement	0.1921	0.7367
	Delayed education and literacy	0.1443	0.2887
	Delayed education and early dropout	0.1629	0.3751
	Child enrollment and schooling achievement	0.1407	0.8573
	Child enrollment and literacy	0.1360	0.3749
	Child enrollment and early dropout	0.2450	0.3176
	Schooling achievement and literacy	0.3696	0.9839
	Schooling achievement and early dropout	0.1560	0.7975
	Literacy and early dropout	0.1503	0.3364

Table 4 continued

Within dimension	Deprivation indicators	V	R^0
Employment	Under- or unemployed and salary	− 0.0451	0.1172
	Under- or unemployed and child labor	0.0117	0.1308
	Under- or unemployed and work or study	− 0.0330	0.6858
	Salary and child labor	0.0219	0.1992
	Salary and work or study	0.0816	0.2531
	Child labor and work or study	0.1572	0.2467

The Cramér's V was calculated only among pair of indicators within each dimension, since tetrachoric correlation matrix did not suggest high correlation between pairs of indicators across dimensions. The tetrachoric correlation matrix is presented in Table 7 in the appendix.

several reasons. First, due to the relevance of each indicator in the NDP 2030, it was determined to be easier to monitor policies based on the individual indicators. Second, each indicator is collected annually in the EPH and there is little cost to including the complete set of indicators. Third, based on robustness analysis results, it was determined that removing any of the indicators, which are all warranted on normative arguments based on their importance in the NDP 2030, would arbitrarily alter the MPI.

3.3.3 Weighting Structure and the Multidimensional Poverty Cutoff

The weighting structure for the dimensions and indicators is presented in Table 2. The weighting structure for the Paraguayan MPI was determined based on an extensive literature review and considerations of comments of the members of the National Inter-Institutional Committee on Poverty Measurement. The four dimensions were considered equally important for the country context, and therefore equally weighted. Similarly, within each dimension all indicators were determined equally important and, thus, equally weighted.

The multidimensional poverty cutoff, denoted by k, represents the minimum deprivation score that determines whether a household and its members are living in multidimensional poverty. Because we use a standardized weighting structure for the dimensions and indicators of the Paraguayan MPI, values of k can range from 0 to 1. The poverty cutoff was chosen to be 0.25, so that an individual is identified as multidimensionally poor if he or she experiences weighted joint deprivations equivalent to being deprived in a full dimension. With this multidimensional poverty cutoff an individual living in multidimensional poverty may be severely (fully) deprived in one dimension, or moderately (jointly) deprived in multiple dimensions. Selecting a multidimensional poverty cutoff equivalent to one full dimension is common in the existing literature. For example, Santos et al. (2015) set the value of k to be equal to 0.25 or deprivation equivalent to a full dimension. The Global MPI uses a value of k equal to 1/3, which is also equal to a full dimension (Alkire et al. 2016).

In addition to selecting a multidimensional poverty cutoff, a number of normative judgments were made about the structure of the MPI, such as which indicators to include and the weighting structure. Therefore, it is important to understand how these decisions affect the MPI. In the following section we explore the robustness of the weighting structure, as well as the poverty cutoff used to create the MPI.

3.3.4 Robustness

To develop an MPI, decisions on a set of parameters have to be made and it is important to have a sense of the robustness of the index to changes in these parameters (Santos 2014; Alkire et al. 2015b). In particular, decisions about the construction of the deprivation indicators, the organization of the indicators within dimensions, the weighting scheme used in aggregating the indicators, and the value of multidimensional poverty cutoff have to be made. Each one of these decisions may effect the MPI and its conclusions about public policy. In order to better understand the effect of these decisions on the MPI, we perform several robustness analyses. Specifically, we investigate the robustness of the MPI to different multidimensional poverty cutoffs and different indicator weighting schemes as suggested by Santos (2014).

First, we consider the robustness of the MPI to changes in the multidimensional poverty cuttoff, k. An MPI is considered robust if altering the multidimensional poverty cuttoff, k, does not alter poverty ranks despite the change in the poverty cuttoff (Alkire et al. 2015b). Hence, the conclusions drawn from the MPI should be maintained. Recall that an individual is in multidimensional poverty if $c_i \geq k$, where c_i is the deprivation score for individual i and k is the multidimensional poverty cutoff. Clearly, a higher multidimensional poverty cutoff k will lead to less people being in multidimensional poverty, because the higher value of k implies a stricter poverty requirement, e.g. being deprived on average in more indicators or dimensions. Likewise, a lower value of k will include more individuals in multidimensional poverty. Thus, an MPI maybe considered robust to the value of the multidimensional poverty line, k, not if it doesn't change with the value of k, but rather if it preserves the ranking of multidimensional poverty over time.

Figure 1 presents estimates of both the multidimensional poverty headcount ratio, H, and the multidimensional poverty index, MPI, for different multidimensional poverty cutoffs, k. These results indicate that the rankings across years are robust for the various values of k.

The second robustness analysis that we perform is to investigate how the MPI is affected by different indicator weighting schemes. Specifically, we investigate the effect of weighting one deprivation indicator zero and re-weighting the remaining indicators within a dimension equally. We maintain equal dimension weights, so that the sum of the weights

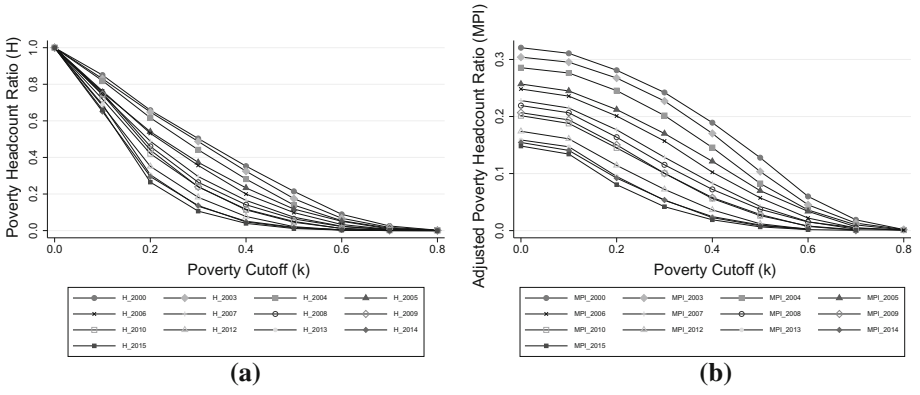


Fig. 1 Robustness of **a** the headcount ratio (H) and the **b** multidimensional poverty index (MPI) to different poverty cutoffs (k)

within each dimension always equals 25%. For example, we begin by changing the weight on water source to zero, which is equivalent to removing the indicator from the MPI. We then increase the weights on the remaining four indicators in the health, water, and sanitation dimension to 6.25% and recalculate the multidimensional poverty headcount ratio, *H*, and the MPI, while holding the multidimensional poverty cutoff, *k*, at 0.25. This is then repeated for each subsequent deprivation indicator.

The results of different indicator weighting schemes are presented in Fig. 2. The results of unadjusted and adjusted multidimensional poverty headcount ratios, *H* and MPI respectively, based on the complete deprivation indicators and weighting scheme described in Table 2 are denoted by "BASE" on the x-axis. The other deprivation indicators listed on the x-axis are those that receive a zero weight during the calculation of the headcount ratio, *H*, and MPI compared to the base case. The vertical line running through each graph splits the graphs into two sections. To the left of the vertical line are weighting schemes that, on average, lower the headcount ratio. To the right of the vertical line are weighting schemes that, on average, increase the headcount ratio.

Again, the ranking of the headcount ratio, *H*, and the MPI appears robust over time to different weighting schemes. In sum, we investigated the robustness of the MPI to different multidimensional poverty cutoffs and different indicator weighting schemes. We found the MPI to be highly robust in terms of rankings and the headcount ratio across years. This robustness analysis has shown that although a number of normative decisions are made when constructing an MPI, altering these decisions should not affect public policies conclusions drawn from it.

4 Results

In this section we present three sets of results. We begin by presenting results for the MPI at different geographical levels. We then investigate the relationship between multidimensional poverty and income poverty, and conclude with a decomposition of the MPI by dimensions.

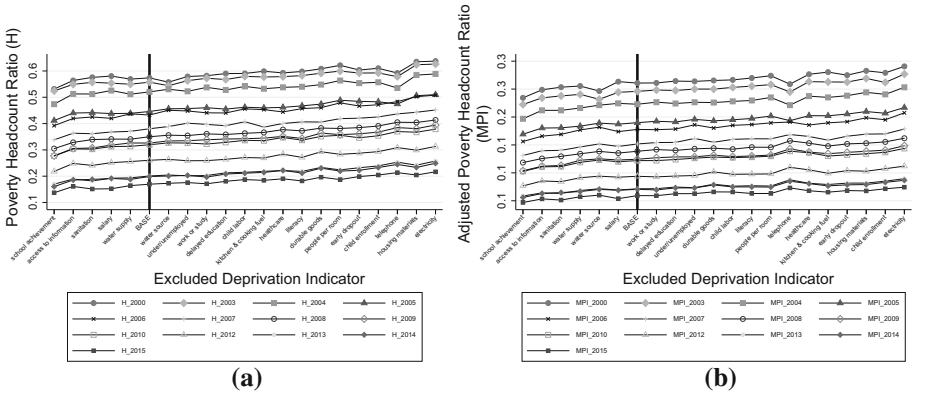


Fig. 2 Robustness of **a** the headcount ratio (H) and **b** the multidimensional poverty index (MPI) to deprivation indicators

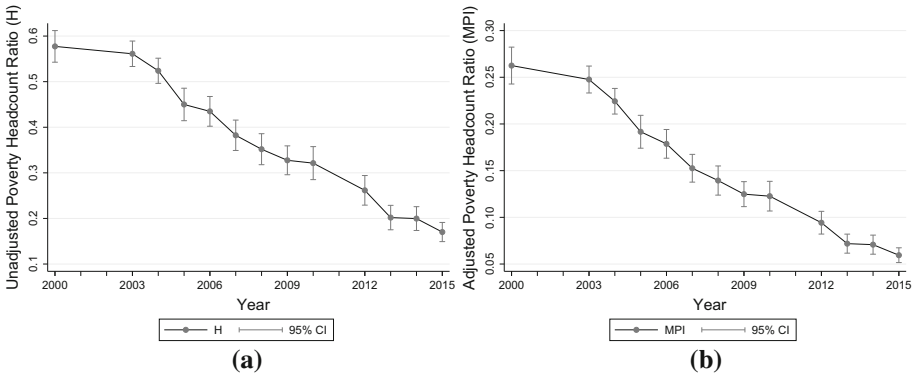


Fig. 3 Multidimensional unadjusted (H) and adjusted (MPI) poverty headcount ratios with 95% confidence intervals. **a** Multidimensional headcount ratio (H), **b** multidimensional poverty index (MPI)

4.1 Multidimensional Poverty Nationally and Regionally

The results of the multidimensional unadjusted (H) and adjusted (MPI) poverty headcount ratios are found in Fig. 3. Nationally, the incidence of multidimensional poverty (H) in Paraguay has declined by an annualized rate of 9.2%, falling from 57.74% in 2000 to 17.02% in 2015. The multidimensional adjusted poverty headcount ratio (MPI) declined even faster than the headcount rate (H) with an annualized rate of 11%, falling from 26.25% in 2000 to 5.96% in 2015.

Ninety-five percent confidence intervals for both multidimensional headcount ratios are provided in the figures.[15] The confidence intervals suggest that the estimates are highly reliable with very small standard errors and that the observed decreases in multidimensional poverty are statistically significant across 5 year periods.

The consistent year-over-year improvement in the Paraguayan MPI suggests reductions in non-monetary deprivations have resulted in long lasting structural changes in multidimensional poverty. The rapid decrease in the adjusted headcount ratio (MPI) compared to the unadjusted headcount ratio (H) indicates that average deprivations among those living in multidimensional poverty, the multidimensional poverty intensity (A), decreased over the period. The results for multidimensional poverty intensity (A), in addition to uncensored and censored headcount ratios by individual deprivation indicators, are presented in Figs. 9, 10, 11, 12 and 13 in the appendix.

The large improvement in multidimensional poverty in Paraguay from 2000 to 2015 could be explained by three main factors: the robust economic growth that the economy experienced in the period of study, the structural changes observed in the labor market, and the urbanization process that has been taking place in the past few decades.

Although economic growth was volatile, Paraguay achieved an average 4% GDP growth rate between 2000 and 2015. During this period, two sub-periods of growth are quite noticeable. The period between 2000 and 2005, where the Paraguayan economy grew at an average rate of 1.6%, and the period between 2006 and 2015, where the average growth rate was about 5.3% (BCP 2017). The sustained growth rate that Paraguay has been experiencing, in particularly since 2003, has been considered pro-poor, as it has translated

[15] Recall from Sect. 3.1 that estimates of standard errors and confidence intervals incorporate survey design and are robust to arbitrary forms of heteroskedasticity that allow within cluster correlation.

into faster increases of the incomes of the bottom 40% of the households (Lopez-Calva et al. 2015). Moreover, social expenditure increased from 10 to 15% of GDP between 2002 and 2014 (Velaztiqui 2015). The robust economic growth and the subsequent increase in social expenditure has allowed the government to expand coverage of basic services, such as water, electricity, and healthcare, reinforcing the income effects on the reduction of multidimensional poverty. With higher income and higher coverage of social programs, households in poverty were able to overcome several deprivations in health, water, sanitation, housing, access to basic goods and services, and employment.

Perhaps more importantly, the period of study was associated with dramatic changes in the labor market. Within the agricultural sector, there has been a movement towards wage employment (Lopez-Calva et al. 2015). At the same time, with the shift of the economy from agriculture to a service-based economy, the majority of new jobs were concentrated in non-agricultural sectors. With this, labor productivity as well as the number of formal jobs increased significantly (Ruppert Bulmer et al. 2017). The combination of higher wages from formal jobs and a reduction in unemployment, allowed households living in poverty to strengthen their capacity to lead a life with better employment conditions, and use higher incomes to purchase more basic goods and services.

Lastly, urbanization may have also played a role in the reduction of multidimensional poverty. With urbanization, non-agricultural sources of income are generated, which are likely to be higher and more stable (Lopez-Calva et al. 2015). Poor rural workers move to cities to work in non-agricultural jobs with higher salaries. With higher paid jobs in urban areas, these workers are able to access more and better goods and services (Cali and Menon 2012). Indeed, there has been an important process of rural-urban migration in Paraguay in the period of study. In 2000, 46.3% of the population lived in rural areas. This share decreased to 39.1% in 2015, and the projections suggest that it will continue to decrease.

In sum, the combination of robust economic growth, changes in the labor market, and urbanization, appear be the driving forces in the reduction of multidimensional poverty in Paraguay in this period.

Figure 4 presents the multidimensional adjusted (MPI) poverty headcount ratio for rural and urban areas. Similar to existing global and regional studies, multidimensional poverty is more severe in rural areas (Santos et al. 2010; Alkire and Santos 2014; Santos et al. 2015).

Despite large decreases in the MPI in both rural and urban areas, the MPI has decreased more rapidly in urban areas, leading to an increase in the rural/urban ratio. The rural/urban ratio is shown in Fig. 4 on the right-hand vertical axis and the diamond plot. This ratio has increased from below 3 before the year 2005 to over 4 following the year 2010. Multidimensional poverty is now approximately 4 times higher in rural areas than in urban areas. This is a combination of both being more likely to be in multidimensional poverty in rural areas as well as facing a higher multidimensional poverty intensity once in poverty in rural areas.

An important factor for understanding the increase in the rural/urban ratio of the MPI in Paraguay is the process of rural-urban migration that the country has been experiencing. In Paraguay, the rural households more likely to migrate are those with better education, and hence with better living conditions (Molinas Vega 1999). Additionally, the unit cost for social service provision is much lower in urban areas than in rural ones. Therefore, the migration of these households to urban areas will only increase multidimensional poverty in rural areas, leading to an increase of the rural/urban ratio.

Finally, we present an analysis of the MPI by departments. Such an analysis is important, because it provides information that can help policy makers evaluate the

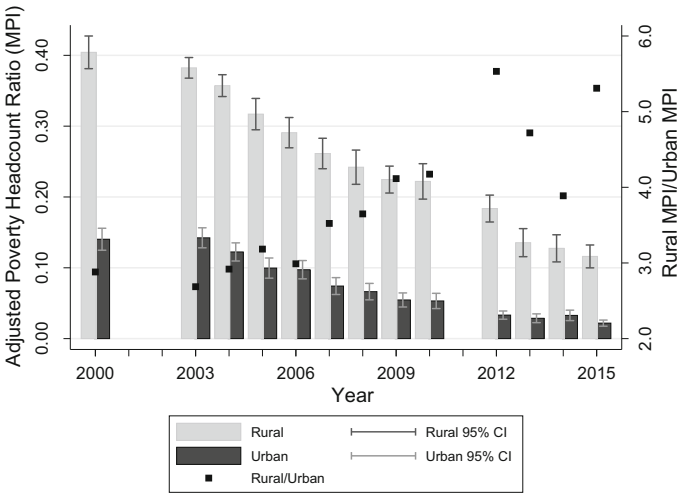


Fig. 4 Multidimensional adjusted poverty headcount ratio (MPI) in rural versus urban areas. *Note*: 2002 and 2011 were omitted from the analysis due to missing data. The 2000 survey was administered in October 2000–February 2001

effectiveness of public policies at the department level and direct resources to geographic locations where the MPI is highest. Furthermore, the analysis by department shows how the MPI has evolved geographically over time to investigate if historically poor regions have been catching up to richer areas.

Figure 5 presents the MPI by department for select years (on the left) and the average annual rate of decline in the MPI by department (on the right). This figure shows how the MPI has geographically evolved over time, and provides several interesting findings. First, the MPI is highest in the department of San Pedro and despite large decreases over the years, the MPI remains highest in San Pedro. San Pedro, followed by Caaguazú, is the most rural department in Paraguay, with the highest rate of the population employed in the informal, agricultural sector. Second, the capital city of Asunción, followed by the department of Central, had the lowest MPI in 2000. However, between 2000 and 2015, the department of Central witnessed the largest year-over-year decline in the MPI, surpassing Asunción as the area with the lowest MPI by 2015. This effect was statistically significant beyond the 5% significance level. In contrast to rural San Pedro and Caaguazú, Central is the department with the lowest informality rate, highest urbanization, and highest education levels.[16]

Despite the significant reduction in multidimensional poverty at the national level, there has not been convergence across departments. These findings highlight challenges in reducing multidimensional poverty in vulnerable, rural populations, where levels of infrastructure have generally been low. Ideally, public policies should use this information to monitor multidimensional poverty by department across time and at the same time to evaluate if public policies at the department levels have had the intended effects. In particular, policy makers should tailor public policies to the departments, so that those with

[16] According the Paraguayan Household Surveys, 94% of the employed population of San Pedro worked in informal sectors and obtained an average of 5.4 years of schooling. In Central, 65% of the employed population worked in informal sectors and obtained 8.3 years of schooling, on average.

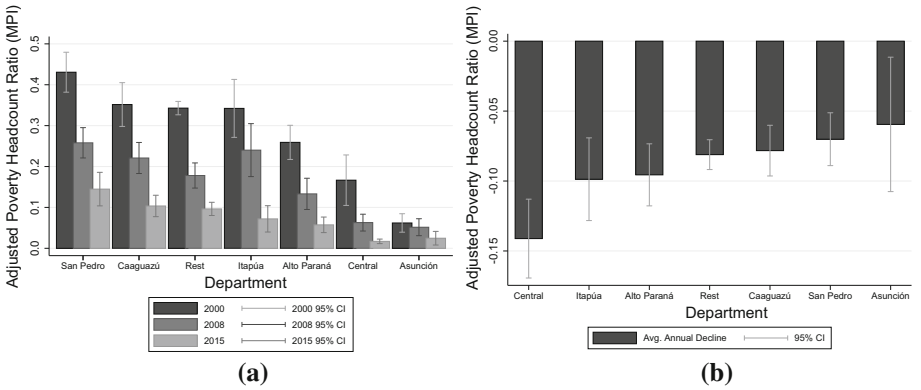


Fig. 5 Multidimensional adjusted poverty headcount ratio (MPI) by department for select years. **a** MPI by departments, select years, **b** average annual rate of decline in MPI by department (2000–2015)

the highest multidimensional poverty could converge to the departments with the lowest levels of multidimensional poverty.[17]

In sum, the geographical distribution of multidimensional poverty helps to understand how this phenomena is spread between urban and rural areas, and across departments. Understanding the distribution of multidimensional poverty will help policy makers in designing and implementing public policies tailored to the needs of the departments and areas, thus increasing their efficiency. Moreover, such an analysis over time will allow for the monitoring and evaluation of implemented public policies. With the frequency that the MPI can be estimated, this analysis will allow for long term public policies to be revised and re-oriented, if necessary, in the short and medium terms.

4.2 Multidimensional Poverty Versus Income Poverty

Figure 6 presents the multidimensional unadjusted (H) poverty headcount ratio and the income (total) poverty headcount ratio. The Government of Paraguay monitors extreme poverty and total poverty based on income measures. Individuals who live on approximately $2 per day or less are considered living in extreme poverty and those who live on approximately $3 per day or less are considered living in (total) poverty. Income poverty lines are constructed from household expenditure surveys, performed in 1997 and 2012, and are adjusted annually for inflation. The extreme poverty line is based on a basic food basket, and food prices, and the total poverty line is the basic food basket plus a basic non-food basket. The income aggregate includes formal labor income, public transfers, remittances, income from self-employment, and the value of self-produced goods for own consumption (DGEEC 2012).

Figure 6 shows that both the incidence of multidimensional poverty and income poverty have experienced a negative trend since 2000. Prior to the year 2006 a larger share of the

[17] The 2015 Paraguayan Household Survey is the first survey representative of 15 of the 17 departments in Paraguay, since the 2003 survey. Figure 14 in the appendix presents the MPI by the individual departments. This information could be used by policy makers to target departments where the MPI is highest.

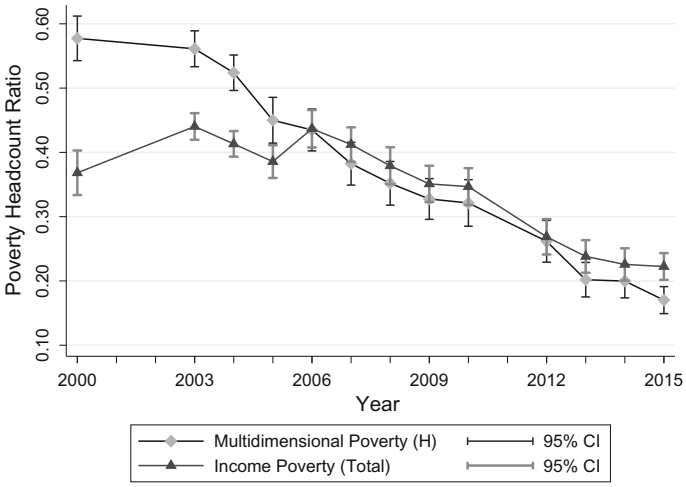


Fig. 6 Income (total) and multidimensional unadjusted (H) poverty headcount ratio and 95% CI

population was living in multidimensional poverty than in income poverty. However, after the year 2006 the share of the population living in multidimensional poverty was slightly lower than in income poverty.

The reductions in both, monetary and multidimensional poverty, are likely due to pro-poor economic growth experienced after the year 2003, which was accompanied by significant structural changes in the labor market, and rapid urbanization. However, at the same time, a rapid increase in food prices, which grew at a faster rate than general prices, affected mainly rural poor households and softened reductions in monetary poverty, by increasing the income poverty line and incorporating more households into poverty (Lopez-Calva et al. 2015).[18] This could explain why the share of the population living in multidimensional poverty fell below income poverty after the year 2006.

Figure 7 presents the composition of the population by poverty status. First, since 2000, there is a clear increase in the percentage of the population not living in multidimensional poverty nor income poverty. Second, the share of the population that is living jointly in multidimensional poverty and income poverty has declined since 2000, particularly after 2006. Absent panel data to observe poverty at the individual level over time, this segment of the population may be considered the *chronic poor*, because they neither earn enough income to lift themselves out of income poverty, nor do they have access to basic goods and services that could provide them the freedom and capability to lead their own lives. Reducing the population living in chronic poverty may help people escape and remain out of poverty.

Categorizing the population by income poverty and multidimensional poverty status is associated with the integrated model for measuring poverty proposed by Beccaria and Minujin (1985) and Katzman (1989). The proportion of the population not in multidimensional poverty but in income poverty has also been declining since 2000. This segment

[18] The extreme poverty line is based on a food basket and only depends on food prices. All things being equal if food prices grow faster than the general CPI, the poverty line increases and incorporates more people into poverty. However, rural households may be net sellers or consumers of food products, making it difficult to determine if food prices will increase or decrease poverty. Lopez-Calva et al. (2015) present a decomposition of changes in extreme poverty and suggest rising food prices were contributing to poverty increases in Paraguay between 2003 and 2011.

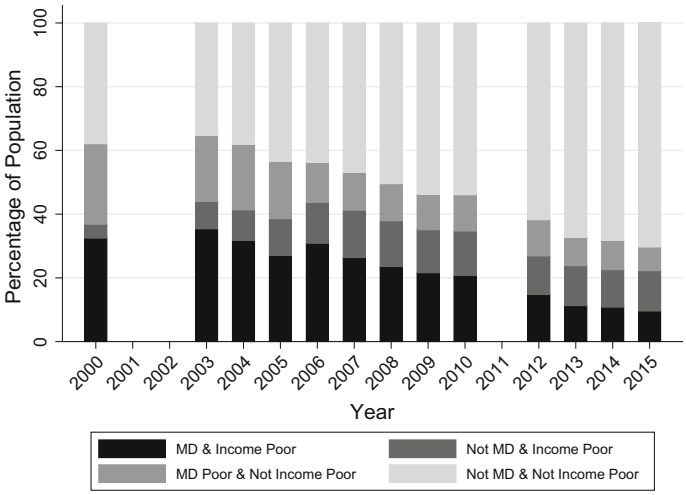


Fig. 7 Population composition by poverty status: income (total) and unadjusted (H) multidimensional (MD) poverty. *Note*: 2002 and 2011 due to missing data. The 2000 survey was administered in October 2000–February 2001

of the population is often referred to as the *recent poor*, since poverty may be a transitory state given income volatility (Katzman 1989). Reductions in this segment of the population suggest lasting structural changes in poverty in all its forms. Lastly and importantly, the population living in multidimensional poverty, but not income poverty has reduced from 25% in 2000 to 7% in 2015. This population is considered the *overlooked poor*, because absent the MPI this population would have remained unobserved.

4.3 Dimension Decomposition

In this section, we present the results of decomposing the MPI by dimension.[19] Such analysis will help understand the dimensions and indicators that contributed the most to the MPI in each year, providing information that can be used by policy makers to prioritize the areas where individuals are most deprived.

Figure 8 presents the contribution of the individual dimensions to the MPI. Historically, the two dimensions housing and basic goods and services and health, water, and sanitation have contributed more to the MPI than education and employment. However, the importance of education and employment appears to be growing.

The contribution of education has increased from 23.2% in 2000 to 28.4% in 2015. Employment's contribution has increased from 11.1% in 2000 to 19.2% in 2015. This may highlight the need to develop future policies to increase education and employment, especially as access to basic goods and services become more available.

[19] A decomposition by individual deprivation indicators is found in Fig. 15 in the appendix.

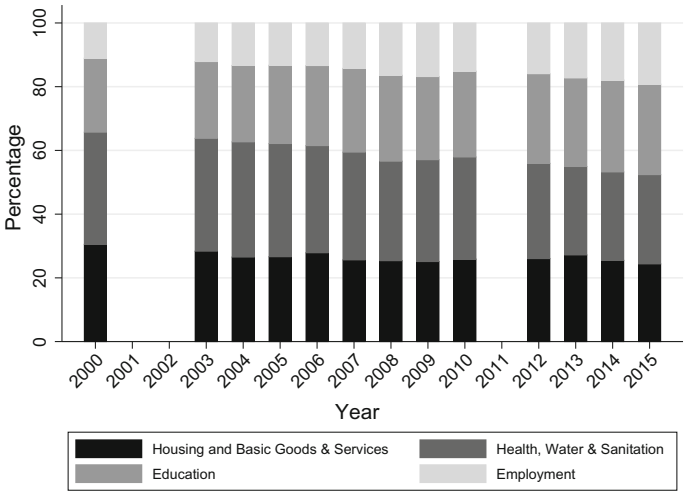


Fig. 8 Contribution of dimension to the multidimensional adjusted poverty headcount ratio (MPI). *Note*: 2002 and 2011 due to missing data. The 2000 survey was administered in October 2000–February 2001

5 Concluding Remarks

In this paper, we proposed a multidimensional poverty index for Paraguay constructed using the Alkire–Foster dual-cutoff method for multidimensional poverty identification (Alkire and Foster 2011). The proposed MPI is composed of 20 deprivation indicators grouped within 4 dimensions. Each of the four dimensions is weighted equally by 0.25. In a similar manner, all deprivation indicators within each dimension are equally weighted. A poverty cutoff of $k = 0.25$ was selected, so that an individual is considered to be living in multidimensional poverty if she experiences weighted joint deprivations equivalent to being deprived in a full dimension. The structure of the MPI is based on the adjusted headcount ratio, the M_0 measure of multidimensional poverty, which combines measures of both multidimensional poverty incidence and multidimensional poverty intensity and satisfies a number of useful axioms on multidimensional poverty measurement.

We made decisions on poverty dimensions for the Paraguayan multidimensional poverty index based on philosophical arguments and the country's development commitments. In particular, we adopt a conceptual framework aligned with both the capabilities approach and the basic needs approach, as this facilitates the incorporation of the national development goals from the NDP 2030 and international development goals from the SDGs in the MPI. In addition, indicators, weighting schemes, and the multidimensional poverty cutoff used in the MPI for Paraguay were determined based on normative judgments on national definitions of poverty, on national and international development priorities, a thorough literature review, and data availability. We also considered comments received from the country's National Inter-Institutional Committee on Poverty Measurement.

The MPI for Paraguay was estimated for the years 2000–2015 using the national household surveys (EPH). The results indicate that multidimensional poverty in Paraguay reduced nationally by more than 77% since 2000. The large decrease observed in the multidimensional poverty appears to be driven by three main factors: robust and pro-poor economic growth, substantial changes in the labor market, and urbanization.

We explore the geographic distribution of the MPI by area of residence and by department. We find that large improvements in the MPI have been observed across all departments, and that similar to income poverty, the MPI is higher in rural areas compared to urban areas. Interestingly, declines in the MPI have not been larger in the areas with a higher initial MPI. In fact, the department of Central, where the MPI has generally been low, witnessed the largest year-over-year decline in the MPI, and overtook the capital city of Asunción as the department with the lowest share of the population living in multidimensional poverty.

The geographic results suggest that while public policies, ideally, should seek both to lower multidimensional poverty and to achieve convergence in multidimensional poverty across departments and regions, this has not been the case. The geographical distribution of multidimensional poverty helps to understand how this phenomena is spread between urban and rural areas, and across departments. Such an analysis can help policy makers to design and implement public policies tailored to the needs of the departments and areas, allowing them at the same time to monitor and evaluate public policies.

Finally, we compare multidimensional poverty with income poverty. We find that both, the incidence of multidimensional poverty and the incidence of income poverty have declined since 2000. Prior to the year 2006, a larger share of the population was living in multidimensional poverty than in income poverty. However, after 2006 the share of the population living in multidimensional poverty has been slightly lower than the share of the population living in income poverty.

The share of the population that is living jointly in multidimensional poverty and income poverty has declined by over 67% since 2000. However, in 2015, about half of the population living in income poverty was also living in multidimensional poverty, and vice versa (approximately 9% of the population). And approximately 7% of the population was estimated to be living in multidimensional but not income poverty.

The reduction of both, multidimensional and income poverty, appear to be driven by the previously stated factors of pro-poor economic growth, labor market improvements, and urbanization. However, the rapid increase in food prices, which grew at a faster rate than general prices, seems to have softened reductions in monetary poverty, resulting in higher levels of income poverty compared to multidimensional poverty after the year 2006.

This is the first MPI proposed for Paraguay rigorously developed using the latest conceptual and methodological developments in the area of multidimensional poverty. The Paraguayan MPI reflects both the country's national development priorities as stated in the National Development Plan 2030 (NDP 2030), as well as international development priorities established in the Sustainable Development Goals (SDG).

The MPI helps to identify people living with acute deprivations that would not be identified with monetary poverty measures alone. The MPI can set the basis for multidimensional proxy means instruments for assistance targeting. Furthermore, the MPI can catalyze strategic action plans for improving lagged indicators such as schooling achievement, access to information, sanitation, employment, improved water, and housing in the case of Paraguay. We hope that our proposed MPI for Paraguay will set the basis for further discussions regarding the needs of adopting this tool as it can be used to more fully assess the impact of public policies on reaching the country's development goals.

Appendix See Tables 5, 6, 7 and Figs. 9, 10, 11, 12, 13, 14 and 15.

Table 5 Missing values of the pooled sample

Dimensions and indicators	Percentage of missing
Health, water, and sanitation	
Water source	0.001
Water supply	0.004
Sanitation	0.006
Kitchen and cooking fuel	0.001
Healthcare	0.010
Housing and basic goods and services	
Housing Materials	0.000
People per room	0.000
Durable goods	0.006
Electricity	0.001
Telephone	0.004
Access to information	0.001
Education	
Delayed Education	0.000
Child enrollment	0.000
Schooling achievement	0.000
Literacy	0.000
Early drop out	0.000
Employment	
Under or unemployed	0.000
Salary	0.000
Child labor	0.000
Work or study	0.000

Table 6 Means and standard deviations for all years

Dimensions and indicators	Years												
	2000	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015
Water source	0.538	0.505	0.327	0.275	0.225	0.210	0.254	0.236	0.226	0.223	0.261	0.252	0.238
	(0.50)	(0.50)	(0.47)	(0.45)	(0.42)	(0.41)	(0.44)	(0.42)	(0.42)	(0.42)	(0.44)	(0.43)	(0.43)
Water supply	0.478	0.414	0.397	0.369	0.325	0.292	0.331	0.297	0.292	0.297	0.331	0.314	0.314
	(0.50)	(0.49)	(0.49)	(0.48)	(0.47)	(0.45)	(0.47)	(0.46)	(0.45)	(0.46)	(0.47)	(0.46)	(0.46)
Sanitation	0.479	0.438	0.423	0.382	0.375	0.335	0.311	0.308	0.310	0.252	0.219	0.200	0.188
	(0.50)	(0.50)	(0.49)	(0.49)	(0.48)	(0.47)	(0.46)	(0.46)	(0.46)	(0.43)	(0.41)	(0.40)	(0.39)
Kitchen	0.113	0.102	0.102	0.074	0.113	0.097	0.079	0.071	0.083	0.080	0.051	0.055	0.035
	(0.32)	(0.30)	(0.30)	(0.26)	(0.32)	(0.30)	(0.27)	(0.26)	(0.28)	(0.27)	(0.22)	(0.23)	(0.18)
Healthcare	0.161	0.096	0.086	0.078	0.178	0.029	0.027	0.037	0.022	0.014	0.019	0.008	0.007
	(0.37)	(0.29)	(0.28)	(0.27)	(0.38)	(0.17)	(0.16)	(0.19)	(0.15)	(0.12)	(0.14)	(0.09)	(0.09)
Housing materials	0.252	0.232	0.233	0.189	0.189	0.191	0.183	0.175	0.177	0.158	0.119	0.115	0.108
	(0.43)	(0.42)	(0.42)	(0.39)	(0.39)	(0.39)	(0.39)	(0.38)	(0.38)	(0.36)	(0.32)	(0.32)	(0.31)
People per room	0.416	0.393	0.374	0.332	0.337	0.325	0.305	0.289	0.286	0.281	0.235	0.225	0.223
	(0.49)	(0.49)	(0.48)	(0.47)	(0.47)	(0.47)	(0.46)	(0.45)	(0.45)	(0.45)	(0.42)	(0.42)	(0.42)
Durable goods	0.521	0.531	0.511	0.460	0.454	0.412	0.336	0.304	0.288	0.185	0.152	0.146	0.130
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.49)	(0.47)	(0.46)	(0.45)	(0.39)	(0.36)	(0.35)	(0.34)
Electricity	0.095	0.080	0.065	0.056	0.030	0.036	0.031	0.025	0.024	0.015	0.006	0.008	0.005
	(0.29)	(0.27)	(0.25)	(0.23)	(0.17)	(0.19)	(0.17)	(0.16)	(0.15)	(0.12)	(0.08)	(0.09)	(0.07)
Telephone	0.624	0.616	0.573	0.450	0.294	0.198	0.099	0.109	0.104	0.047	0.038	0.033	0.024
	(0.48)	(0.49)	(0.49)	(0.50)	(0.46)	(0.40)	(0.30)	(0.31)	(0.31)	(0.21)	(0.19)	(0.18)	(0.15)
Access to information	0.967	0.869	0.871	0.834	0.850	0.851	0.813	0.767	0.757	0.576	0.507	0.488	0.477
	(0.18)	(0.34)	(0.33)	(0.37)	(0.36)	(0.36)	(0.39)	(0.42)	(0.43)	(0.49)	(0.50)	(0.50)	(0.50)
Delayed education	0.334	0.331	0.300	0.302	0.308	0.266	0.256	0.222	0.243	0.212	0.184	0.169	0.155
	(0.47)	(0.47)	(0.46)	(0.46)	(0.46)	(0.44)	(0.44)	(0.42)	(0.43)	(0.41)	(0.39)	(0.37)	(0.36)

Table 6 continued

Dimensions and indicators	Years												
	2000	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015
Child enrollment	0.105	0.143	0.087	0.080	0.072	0.068	0.061	0.048	0.044	0.033	0.026	0.029	0.024
	(0.31)	(0.35)	(0.28)	(0.27)	(0.26)	(0.25)	(0.24)	(0.21)	(0.20)	(0.18)	(0.16)	(0.17)	(0.15)
Schooling achievement	0.711	0.681	0.662	0.621	0.617	0.593	0.593	0.543	0.563	0.529	0.488	0.490	0.465
	(0.45)	(0.47)	(0.47)	(0.49)	(0.49)	(0.49)	(0.49)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Literacy	0.228	0.221	0.223	0.200	0.174	0.166	0.171	0.155	0.151	0.149	0.130	0.132	0.117
	(0.42)	(0.41)	(0.42)	(0.40)	(0.38)	(0.37)	(0.38)	(0.36)	(0.36)	(0.36)	(0.34)	(0.34)	(0.32)
Early dropout	0.154	0.129	0.120	0.113	0.117	0.129	0.108	0.107	0.103	0.080	0.069	0.074	0.069
	(0.36)	(0.34)	(0.33)	(0.32)	(0.32)	(0.34)	(0.31)	(0.31)	(0.30)	(0.27)	(0.25)	(0.26)	(0.25)
Under- or unemployed	0.145	0.141	0.152	0.122	0.093	0.092	0.126	0.141	0.107	0.118	0.105	0.112	0.110
	(0.35)	(0.35)	(0.36)	(0.33)	(0.29)	(0.29)	(0.33)	(0.35)	(0.31)	(0.32)	(0.31)	(0.32)	(0.31)
Salary	0.140	0.185	0.178	0.188	0.182	0.216	0.201	0.180	0.177	0.145	0.148	0.143	0.182
	(0.35)	(0.39)	(0.38)	(0.39)	(0.39)	(0.41)	(0.40)	(0.38)	(0.38)	(0.35)	(0.35)	(0.35)	(0.39)
Child labor	0.118	0.115	0.146	0.112	0.096	0.093	0.121	0.110	0.087	0.074	0.063	0.057	0.042
	(0.32)	(0.32)	(0.35)	(0.32)	(0.29)	(0.29)	(0.33)	(0.31)	(0.28)	(0.26)	(0.24)	(0.23)	(0.20)
Work or study	0.171	0.162	0.159	0.148	0.160	0.156	0.128	0.143	0.132	0.110	0.098	0.104	0.103
	(0.38)	(0.37)	(0.37)	(0.36)	(0.37)	(0.36)	(0.33)	(0.35)	(0.34)	(0.31)	(0.30)	(0.31)	(0.30)

Standard deviation in parentheses. Since the indicators are defined as deprivation indicators, these statistics show average proportion of people deprived in each indicator

Table 7 Tetrachoric correlations matrix for pooled sample

Deprivation indicators	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
(1) Water source	1.000																			
(2) Water supply	0.841	1.000																		
(3) Sanitation	0.703	0.482	1.000																	
(4) Kitchen	0.327	0.073	0.426	1.000																
(5) Healthcare	0.348	0.258	0.430	0.184	1.000															
(6) Housing materials	0.569	0.359	0.810	0.432	0.360	1.000														
(7) People per room	0.319	0.140	0.453	0.376	0.276	0.470	1.000													
(8) Durable goods	0.550	0.262	0.672	0.531	0.399	0.647	0.389	1.000												
(9) Electricity	0.665	0.451	0.728	0.440	0.306	0.666	0.353	0.779	1.000											
(10) Telephone	0.569	0.340	0.637	0.358	0.421	0.537	0.325	0.717	0.677	1.000										
(11) Access to information	0.278	0.120	0.657	0.487	0.404	0.630	0.384	0.723	0.747	0.656	1.000									
(12) Delayed education	0.159	0.113	0.297	0.158	0.243	0.242	0.357	0.175	0.146	0.189	0.265	1.000								
(13) Child enrollment	0.332	0.268	0.424	0.197	0.292	0.357	0.422	0.329	0.353	0.340	0.342	0.277	1.000							
(14) Schooling achievement	0.325	0.273	0.600	0.312	0.379	0.527	0.299	0.465	0.456	0.503	0.484	0.289	0.384	1.000						
(15) Literacy	0.306	0.238	0.463	0.215	0.279	0.412	0.121	0.390	0.370	0.396	0.390	0.231	0.305	0.815	1.000					
(16) Early dropout	0.218	0.204	0.359	0.141	0.227	0.301	0.318	0.230	0.223	0.192	0.258	0.309	0.484	0.319	0.284	1.000				
(17) Under- or unemployed	0.021	−0.036	0.009	0.122	0.071	−0.025	0.100	0.046	0.015	0.025	0.078	0.055	0.038	−0.009	−0.036	0.016	1.000			
(18) Salary	0.020	−0.009	0.096	0.172	0.003	0.035	0.193	0.148	0.076	0.069	0.168	0.091	0.080	0.102	−0.021	0.070	−0.126	1.000		

Table 7 continued

Deprivation indicators	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
(19) Child labor	0.222	0.186	0.370	0.126	0.246	0.294	0.328	0.206	0.189	0.211	0.282	0.489	0.583	0.287	0.208	0.360	0.044	0.065	1.000	
(20) Work or study	0.181	0.198	0.332	0.056	0.209	0.276	0.255	0.140	0.163	0.146	0.188	0.299	0.368	0.273	0.249	0.812	−0.081	0.178	0.323	1.000

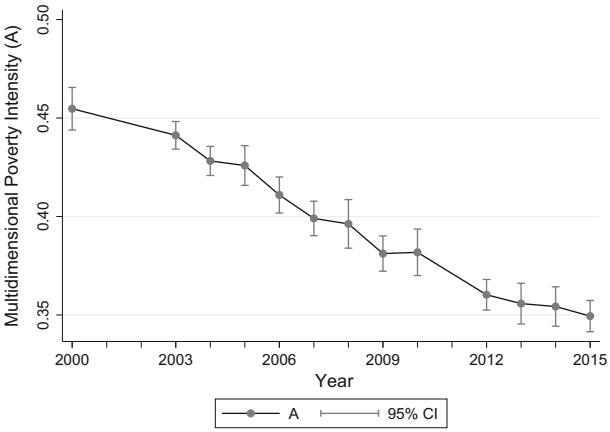
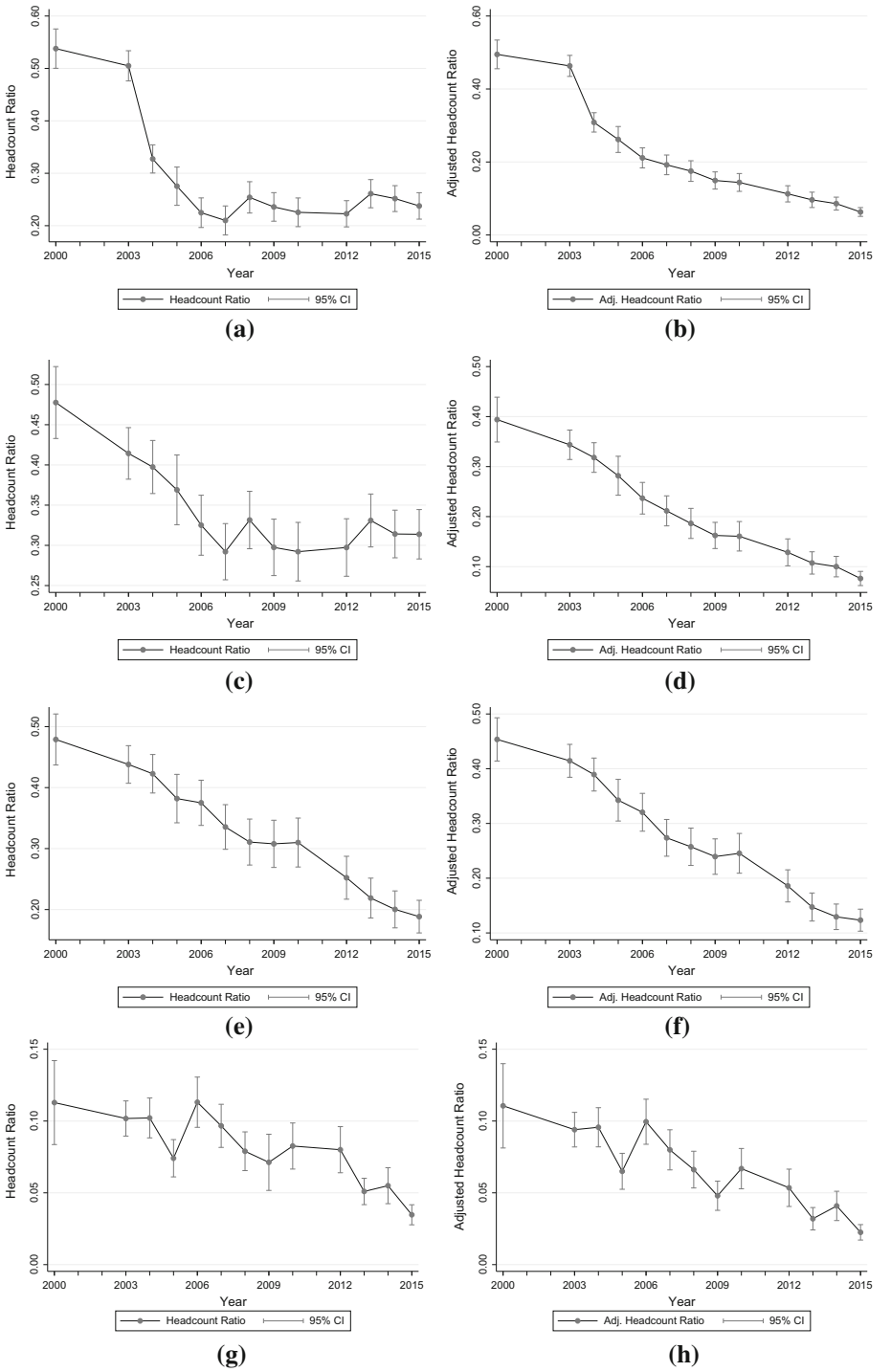
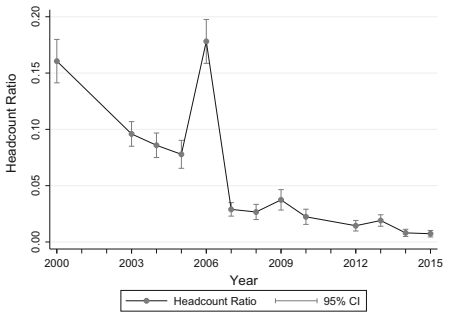


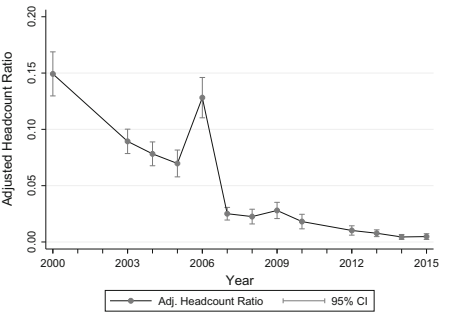
Fig. 9 Multidimensional poverty intensity (A)


Headcount Ratio
Adjusted Headcount Ratio
Year
Headcount Ratio
Adj. Headcount Ratio
95% CI
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)

◀**Fig. 10** Indicators' deprivation headcount ratios and their 95% confidence intervals in the health, water, and sanitation dimension. **a** Uncensored water source deprivation indicator, **b** censored water source deprivation indicator, **c** uncensored water supply deprivation indicator, **d** censored water supply deprivation indicator, **e** uncensored sanitation deprivation indicator, **f** censored sanitation deprivation indicator, **g** uncensored kitchen and cooking fuel deprivation indicator, **h** censored kitchen and cooking fuel deprivation indicator, **i** uncensored healthcare deprivation indicator, **j** censored healthcare deprivation indicator

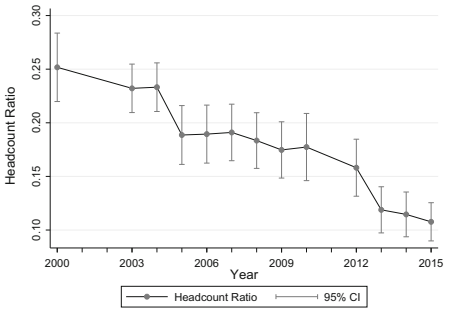


(i)

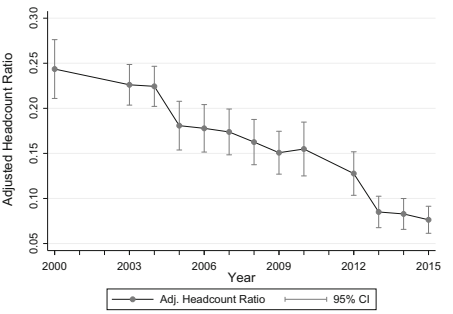


(j)

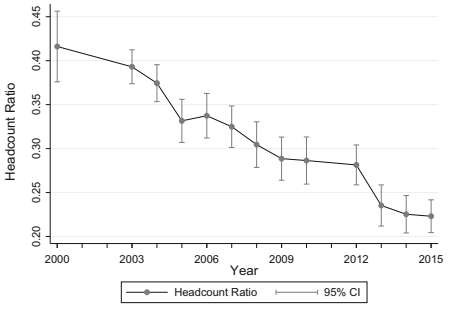
Fig. 10 continued


Headcount Ratio
0.10
0.15
0.20
0.25
0.30
2000
2003
2006
2009
2012
2015
Year
Headcount Ratio
95% CI

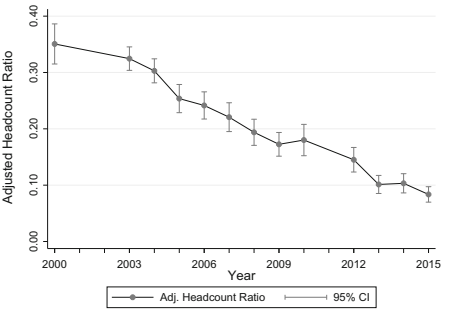
(a)


Adjusted Headcount Ratio
0.05
0.10
0.15
0.20
0.25
0.30
2000
2003
2006
2009
2012
2015
Year
Adj. Headcount Ratio
95% CI

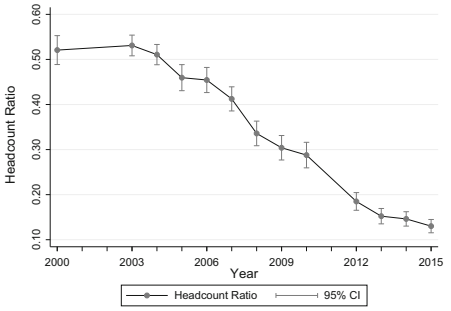
(b)


Headcount Ratio
0.20
0.25
0.30
0.35
0.40
0.45
2000
2003
2006
2009
2012
2015
Year
Headcount Ratio
95% CI

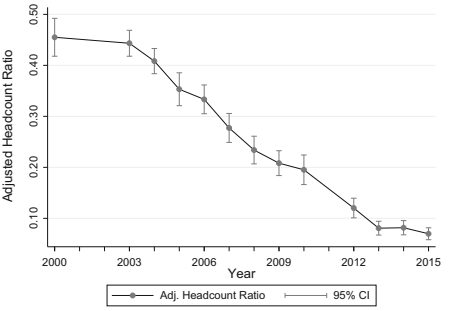
(c)


Adjusted Headcount Ratio
0.00
0.10
0.20
0.30
0.40
2000
2003
2006
2009
2012
2015
Year
Adj. Headcount Ratio
95% CI

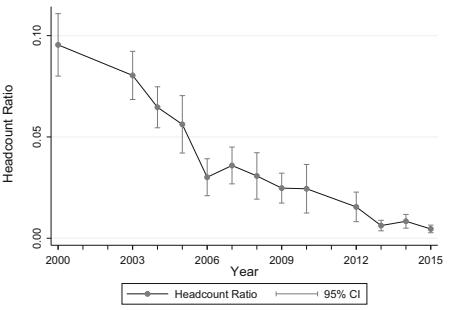
(d)


Headcount Ratio
0.10
0.20
0.30
0.40
0.50
0.60
2000
2003
2006
2009
2012
2015
Year
Headcount Ratio
95% CI

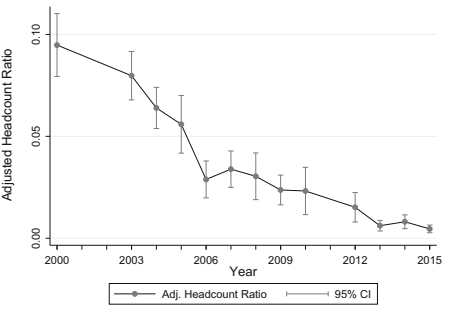
(e)


Adjusted Headcount Ratio
0.10
0.20
0.30
0.40
0.50
2000
2003
2006
2009
2012
2015
Year
Adj. Headcount Ratio
95% CI

(f)


Headcount Ratio
0.00
0.05
0.10
2000
2003
2006
2009
2012
2015
Year
Headcount Ratio
95% CI

(g)


Adjusted Headcount Ratio
0.00
0.05
0.10
2000
2003
2006
2009
2012
2015
Year
Adj. Headcount Ratio
95% CI

(h)

◀**Fig. 11** Indicators' deprivation headcount ratios and their 95% confidence intervals in the housing and basic goods and services dimension. **a** Uncensored housing materials deprivation indicator, **b** censored housing materials deprivation indicator, **c** uncensored people per room deprivation indicator, **d** censored people per room deprivation indicator, **e** uncensored durable goods deprivation indicator, **f** censored durable goods deprivation indicator, **g** uncensored electricity deprivation indicator, **h** censored electricity deprivation indicator, **i** uncensored telephone deprivation indicator, **j** censored telephone deprivation indicator, **k** uncensored access to information deprivation indicator, **l** censored access to information deprivation indicator

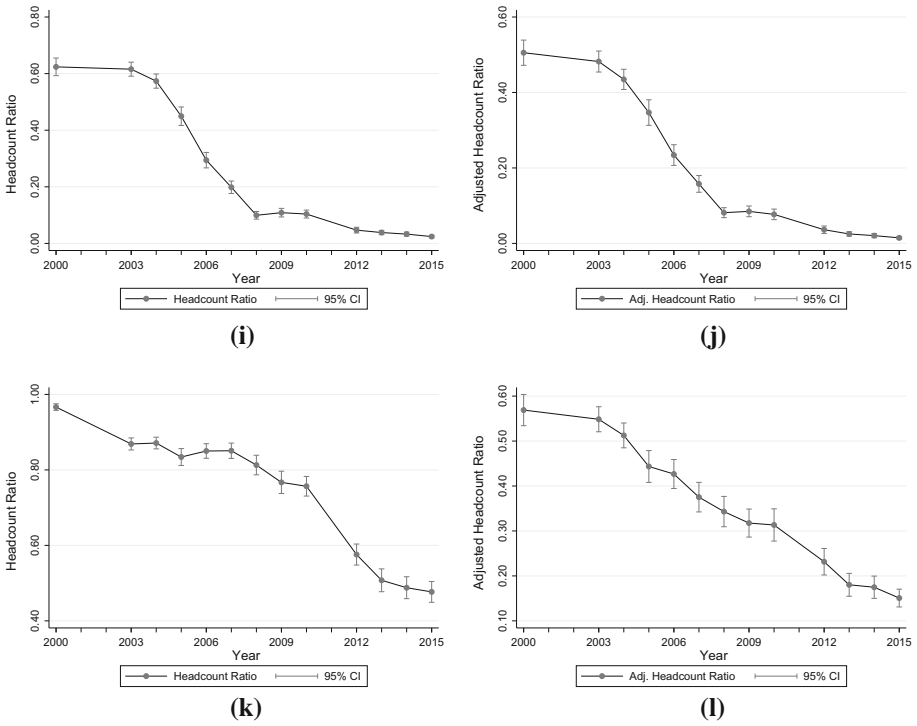


Fig. 11 continued

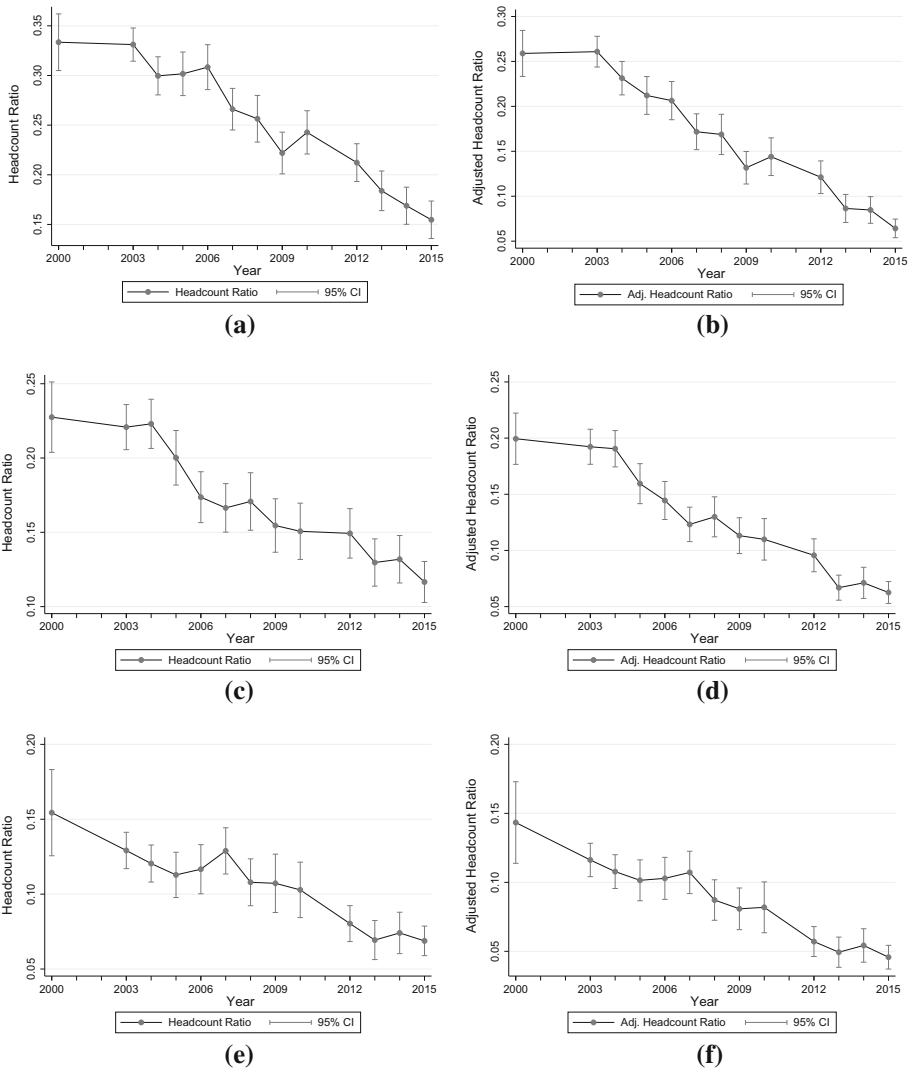
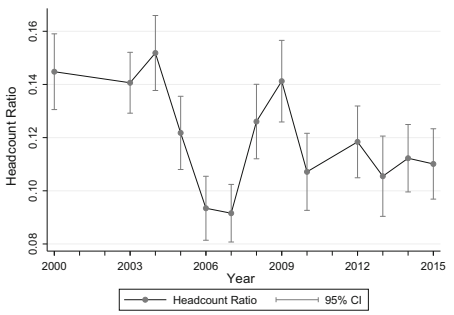
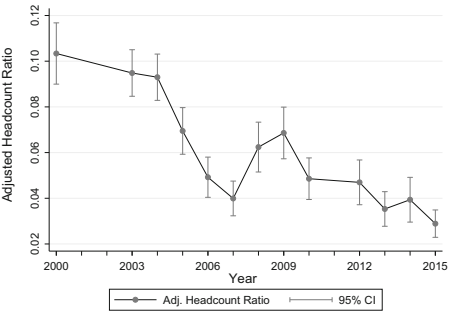


Fig. 12 Indicators' deprivation headcount ratios and their 95% confidence intervals in the education dimension. **a** Uncensored delayed education deprivation indicator, **b** censored delayed education deprivation indicator, **c** uncensored literacy deprivation indicator, **d** censored literacy deprivation indicator, **e** uncensored early dropout deprivation indicator, **f** censored early dropout deprivation indicator

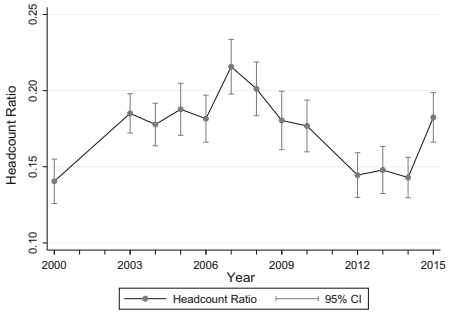
Fig. 13 Indicators' deprivation headcount ratios and their 95% confidence intervals in the employment dimension. **a** Uncensored under- or unemployed deprivation indicator, **b** censored under- or unemployed deprivation indicator, **c** uncensored salary deprivation indicator, **d** censored salary deprivation indicator, **e** Uncensored child labor deprivation indicator, **f** censored child labor deprivation indicator, **g** uncensored work or study deprivation indicator, **h** censored work or study deprivation indicator


Headcount Ratio
0.08
0.10
0.12
0.14
0.16
2000
2003
2006
2009
2012
2015
Year
Headcount Ratio
95% CI

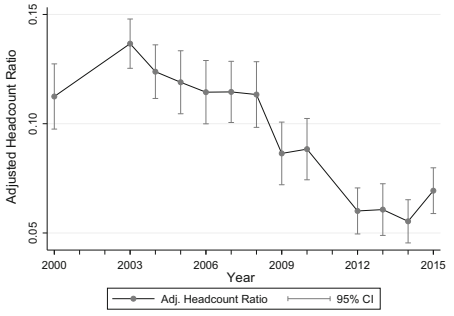
(a)


Adjusted Headcount Ratio
0.02
0.04
0.06
0.08
0.10
0.12
2000
2003
2006
2009
2012
2015
Year
Adj. Headcount Ratio
95% CI

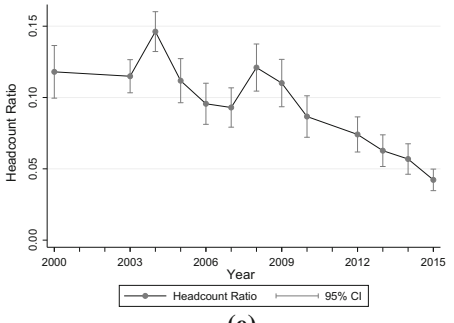
(b)


Headcount Ratio
0.10
0.15
0.20
0.25
2000
2003
2006
2009
2012
2015
Year
Headcount Ratio
95% CI

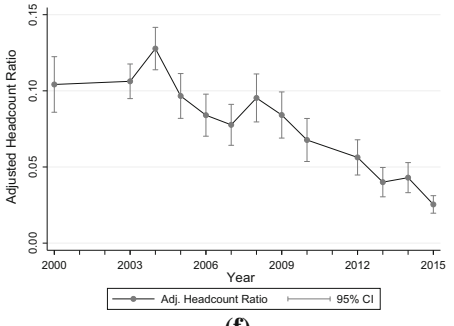
(c)


Adjusted Headcount Ratio
0.05
0.10
0.15
2000
2003
2006
2009
2012
2015
Year
Adj. Headcount Ratio
95% CI

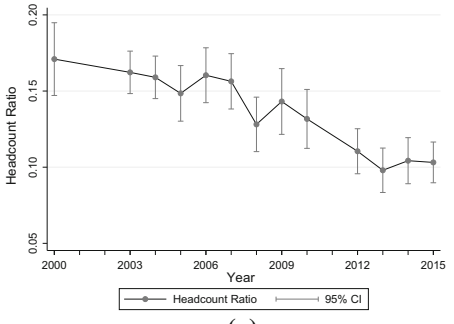
(d)


Headcount Ratio
0.00
0.05
0.10
0.15
2000
2003
2006
2009
2012
2015
Year
Headcount Ratio
95% CI

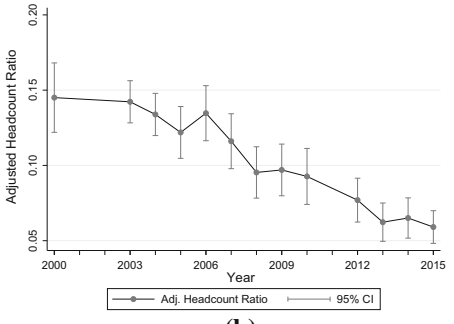
(e)


Adjusted Headcount Ratio
0.00
0.05
0.10
0.15
2000
2003
2006
2009
2012
2015
Year
Adj. Headcount Ratio
95% CI

(f)


Headcount Ratio
0.05
0.10
0.15
0.20
2000
2003
2006
2009
2012
2015
Year
Headcount Ratio
95% CI

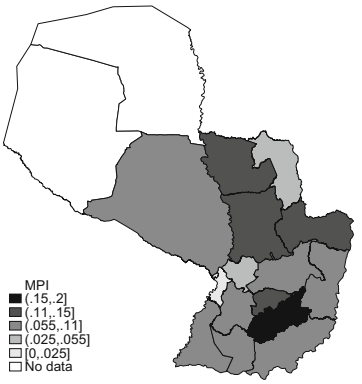
(g)


Adjusted Headcount Ratio
0.05
0.10
0.15
0.20
2000
2003
2006
2009
2012
2015
Year
Adj. Headcount Ratio
95% CI

(h)

Rank	Department	MPI	S.E.	95% CI
16	Caazapá	0.1768	0.027	[0.124, 0.229]
15	San Pedro	0.1448	0.021	[0.104, 0.186]
14	Canindeyú	0.1329	0.036	[0.063, 0.203]
13	Guairá	0.1327	0.023	[0.088, 0.178]
12	Concepción	0.1234	0.025	[0.075, 0.172]
11	Caaguazú	0.1035	0.013	[0.077, 0.130]
10	Paraguarí	0.1016	0.013	[0.076, 0.127]
9	Ñeembucú	0.1001	0.018	[0.065, 0.135]
8	Itapú	0.0720	0.016	[0.040, 0.104]
7	Alto Paraná	0.0574	0.010	[0.038, 0.076]
6	Misiones	0.0569	0.014	[0.029, 0.085]
5	Pdte. Hayes	0.0557	0.015	[0.026, 0.086]
4	Amambay	0.0400	0.012	[0.017, 0.063]
3	Cordillera	0.0375	0.010	[0.017, 0.058]
2	Asunción	0.0247	0.009	[0.008, 0.041]
1	Central	0.0170	0.003	[0.011, 0.023]
-	Boquerón	no data	—	—
-	Alto Paraguay	no data	—	—

(a)



(b)

Fig. 14 MPI by Departments 2015. **a** MPI by department (2015), **b** map of MPI by department (2015)

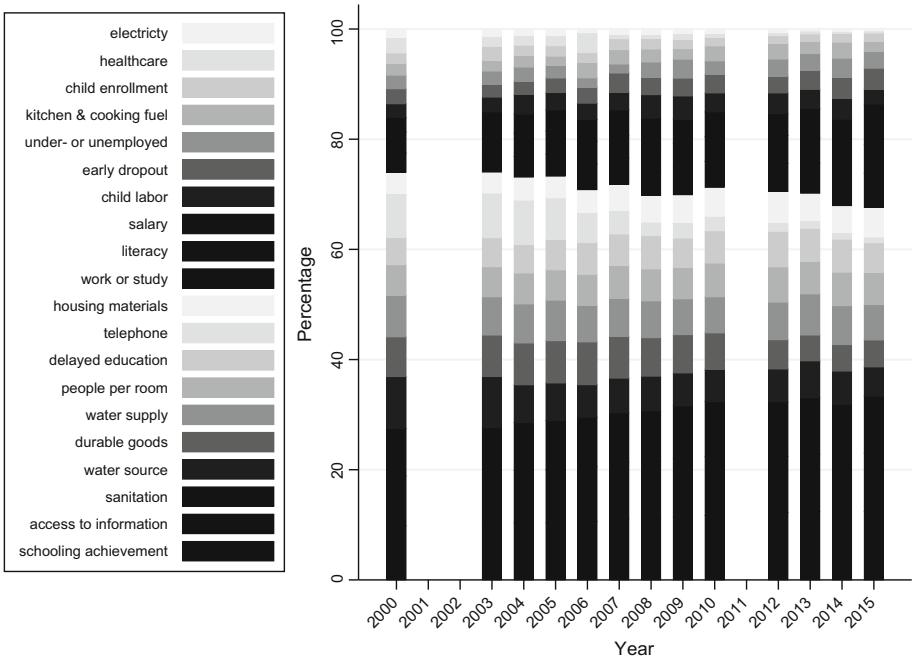


Fig. 15 Contribution of indicator to the multidimensional adjusted (MPI) poverty headcount ratio. *Note*: 2002 and 2011 due to missing data. The 2000 survey was administered in October 2000–February 2001

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