

Estimating poverty: A state-of-the-art of methods

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ABSTRACT

In the report “Poverty and Shared Prosperity 2018: Piecing Together the Poverty Puzzle”, the World Bank points out that “as the world gets richer and progress is made in the battle against extreme poverty, we must not forget that many around the world still live in deprivation, unable to meet their basic needs, even if their income is higher than the International Poverty Line”. This statement establishes two challenges: 1) understanding the complexity of poverty as a multidimensional phenomenon, and, 2) choosing an adequate measure mechanism, which increases data accuracy of poverty, obtaining the closest representation of living conditions of poor people.

Nowadays, the compilation of poverty data is a high-cost task for governments due the need of a great amount of financial and human resources. This limitation makes it almost impossible to rely on immediate updated information. This article compiles the evolution of poverty measurement methods and alternatives to gather poverty data that can reduce the costs and time required to update such information.

CCS Concepts

Information systems → Data analytics

Keywords

Deprivation; poverty; poverty measure; multidimensional approach; unidimensional approach.

1. INTRODUCTION

Poverty is defined as the lack of resources to achieve basic needs for adequate living conditions; therefore, it is a difficult situation to overcome. It is also related to the subsistence and deprivation of resources, capabilities and rights [3,13].

The division of the population into poor and non-poor is not only the result of the presence or absence of income [45]. Rather, poverty refers to the degree of quality living conditions of each

household and its members [8,17,43]. A multidimensional perspective of poverty considers this quality degree, defining poverty as a more complex problem. Therefore, it requires other public policies to increase human capital in order to reduce household poverty [45]. Multidimensional poverty measures provide an alternative viewpoint through which poverty may be better understood.

A multidimensional poverty approach facilitates the understanding of poverty as the inability to reach minimum well-being standards, which cannot be measured solely as a monetary value. This concept broadens the income conception of poverty. Due to this more complete vision of the poverty phenomenon, it is possible to explore alternative methods to deal with it [3,45].

This work offers a review of how poverty has been measured in the past, and how it is measured today. A systematic literature review was performed following the guidelines proposed by Kitchenham [29] concerning the mechanisms currently used to measure poverty and to identify unidimensional and multidimensional perspectives. The research question that guided our review is: Which are the mechanisms used to measure poverty? This question allows the identification of diverse mechanisms, which can be applied in measuring poverty by considering different factors that affect households and/or individuals.

This paper is organized as follows: in section II, we describe the research process that guided our review. This is followed by a presentation of our main results in section III. In section IV, we present a discussion of our results. Section V presents the conclusions of our work where new opportunities of research are also offered.

2. LITERATURE REVIEW METHODS

The goal of this review is to identify the mechanisms used to measure poverty. The research was first focused on articles and documents describing the process for measuring poverty that considers household or individual monetary factors. Secondly, we focused our work on publications referring to non-monetary factors that measure poverty. Finally, we reviewed documents describing methods for collecting household data in order to generate poverty indexes. For our review, the term “household” will be used to determine an individual or group, related or not, who live in the same place of residence and share basic costs [7]. The period of the review was from 2013 to 2018. However, during the review, other studies were identified, which were published prior to 2013. These studies were included because they describe how poverty was measured in previous years. Thus, we have the trace of how poverty measures have changed and which the reasons for these new conceptualizations are.

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The following combination was used as a search string: (poverty OR deprivation) AND (measure OR measurement) AND (multidimensional OR unidimensional OR income). These keywords were searched in the title, keyword, and abstract fields of journal articles using the search engines of SCOPUS, Google Scholar and ELSEVIER.

The results of the search are shown in Table 1. It shows the order in which the bibliographic databases were consulted. More than six hundred publications (646) were found. Subsequently, the abstracts, study objectives, conclusions and future works (if any) of those publications were reviewed. Finally, 128 publications, that comply with the selection criteria and contribute to answering our research question, were selected. All the selected articles come from scientific journals.

Table 1. Results of the Review in Bibliographic Databases

Source	Searched	Selected
Scopus	549	114
Google Scholar	11	11
Elsevier	78	3
Total	646	128

The selected articles (128) were grouped into four categories depending on the study carried out in each document. The categories are: 1) definition of poverty, 2) multidimensional poverty, 3) unidimensional poverty, and, 4) alternative data sources.

A critical review was made of each article. The papers that best suited the objective of this study were chosen. In this way, the following table shows the number of papers that were finally discarded and accepted.

Table 2. Results of the Review of Articles

Category	Discarded	Accepted
Definition of poverty	28	5
Multidimensional poverty	30	22
Unidimensional poverty	4	6
Alternative data sources	21	12
Total	83	45

3. RESULTS

3.1 Theoretical Background

Adam Smith (1776) described poverty as the lack of resources to face needs. The European Council of 1984 defined poverty as the limitation of resources which excluded individuals or households from the minimum adequate level of life, according to the reality of the country where they lived [15].

Nurliyana et al. express poverty as a multifaceted phenomenon associated with a lack of economic resources. Therefore, a person is classified according to his or her economic resource level as follows [33]:

1. Needy, a person who cannot afford his or her vital needs for the day (no economic resources).
2. Poor, a person who cannot afford his or her basic needs (insufficient resources)
3. Non-poor, a person who has enough resources to supply his or her basic needs.

Alternatively, the United Nations Development Programme (UNDP) defines poverty as “more than a lack of what is necessary for material well-being. It can also mean the denial of opportunities and choices in basic aspects of human development that could lead long, healthy, creative life and enjoy a decent standard of living, freedom, dignity, self-esteem and the respect of others” [28]. Therefore, poverty is based on terms of subsistence, lack of basic needs and relative deprivation or scarcity of resources, capabilities, rights and goods. It is also associated with social exclusion. Bourguignon and Chakravarty express that population well-being and poverty depend on monetary and non-monetary variables [20]. Thus, poverty is more than the lack of money, it is the result of other household and environment characteristics [13,15].

The measurement of poverty is important because through it policy makers can become aware of who and where poor people are in order to allocate funds to support poverty reduction policies and improve living conditions of poor households [15,37].

Hence, Bellido et al. consider that the construction of an index of poverty, using available data of poor people, allows the definition of an appropriate and useful poverty measure [15].

Alkire and Foster explain that there are two important parts to measuring poverty [4]:

1. Identification, which consists of identifying people who are below the established threshold and, therefore, considered poor.
2. Aggregation, which consists of a numerical poverty measure that determines the distribution of individuals along the poverty spectrum.

3.2 Analysis of the Evolution of the Methods

There are two approaches for measuring poverty: unidimensional and multidimensional.

3.2.1 Unidimensional Approach

A unidimensional approach uses the single variable of income to represent well-being [13]. The income measures living standards, economic status and achievements of an individual or a household [13,39].

Unidimensional methods establish a threshold (cut-off or poverty line) to determine who is poor [4]. A person is considered poor if his or her income or monetary value of his or her achievements is below a predefined threshold [5,10].

According to Alkire and Foster, unidimensional methods are best applied when a single-dimension resource variable is well defined. Variables include, but are not limited to, years of schooling, self-reported health, and access to drinking water. Traditionally, income has been selected as the basis for poverty measurement [4]. Also, income indirectly provides information of other well-being factors such as access to health care, education, housing, among others [1].

3.2.1.1 How has Unidimensional Poverty been measured?

Unidimensional poverty has been measured by ratios or percentages of total population.

In this case, the head count ratio (H) or incidence of poverty is the ratio calculated from the number of poor people over the total population. Another indicator is the poverty gap or intensity of poverty, which is the aggregate amount of income that households lack to reach the poverty line. Therefore, it could be considered as the deprivation degree of poor people. Both indicators measure the amount of resources necessary for a whole country population to reach the poverty line [38].

Hill and Adrangi explain that poor people are individuals who cannot attain the minimal amount of money to achieve minimal needs. The consumer price index, which considers only the essential goods for surviving, is used as a unidimensional poverty measure too [28].

The use of income or consumption data is due to the facility with which they are obtained. Income data is extracted from the data of the previous calendar year, and consumption data is continuously reported [19]. Thus, poverty can be calculated and provide faster information for policy makers.

However, other factors like health care, education and capital, are not considered within unidimensional measures [28]. It is important to go beyond an income approach to understand other characteristics of households. These provide a complete view of a household situation, making the construction of better public policies possible. Neckerman et al. conclude that to only consider an income perspective underestimates other household features, which provide more information on the real situation of household living conditions [31].

3.2.2 Multidimensional Approach

Bourguignon and Chakravarty [20] define the multidimensional approach of poverty as a decline of several factors or dimensions, which affect living conditions from a defined threshold or cut-off [4,17,36]. This approach establishes separate cut-offs for each dimension of poverty and considers that a household is poor if it falls below the cut-off in at least one of these various lines [1,20]. Multidimensional poverty measures goods and services which determine a household's well-being, and that may help in identifying aspects not captured only by income [13,20]. Multidimensional approach methods include the following steps [1]:

1. Selection of the relevant dimensions
2. Design of indicators used to measure dimensions
3. Establishment of weighting procedures for dimensions

The selection of relevant dimensions depends on the country and its policies in the context of the current state of the population. The capability approach establishes that the individual is at the center of the definition of poverty because of his or her capabilities to achieve things that give value to his or her life. In other words, what an individual can do and be. The capability approach includes other domains, which consider integrity, emotions, affiliation, health, and others [1,36].

Once the dimensions are selected, multidimensional methods have two forms of identification or categorization of people as poor [4]:

1. Union identification, which considers any person deprived in one of the dimensions as poor.
2. Intersection identification, which considers a person is poor if he or she is deprived in all dimensions.

Union identification is not useful when the number of dimensions is large. Deprivations in certain dimensions would identify most of the population as poor even though these people would not be considered poor (inclusion error). In contrast, the intersection method may not identify poor people who have a low-level of deprivation in a single dimension. Although, these people have high-level deprivation in the rest of the dimensions, they are not considered poor because those dimensions are not selected for the determination of poverty measurements (exclusion error) [5].

According to the World Bank, the multidimensional approach shows how deprivations interact with the living conditions of each country and each individual. In regions like Latin America, deprivations are not totally associated with income poverty, they are also related to higher crime rates and insecurity [45]. Therefore,

the multidimensional approach provides new evidence of who is poor or not.

3.2.2.1 How has Multidimensional Poverty been measured?

In order to design the indicators to measure dimensions, it is important to understand that multidimensional methods use two vectors. The first one consists of an individual's achievements, and the second one is made up of an individual's achievement levels in each dimension. The combination of these vectors builds a matrix which allows the measurement method to take advantage of the information contained in the joint distribution of achievements [4]. Another concept used in the multidimensional approach is the term "deprivation", which is a living standard that is below society's average notion of adequate living conditions [13]. A person is deprived when his or her achievements of a specific dimension are below of its defined cut-off [5].

One multidimensional measure is the Human Development Index (HDI), developed by UNDP, which considers three basic dimensions: life expectancy, access to knowledge, and a decent standard of living. [1,6,28]. These dimensions have data in every country, and its thresholds can be defined and understood worldwide. The HDI represents the level of human development obtained in a specific country. Therefore, dimensions must be selected by each country according to its current reality.

Another measure is the Townsend deprivation index, which consists of representing poverty as an n-dimensional vector. Each component measures the individual deprivation level of selected goods and services which are essential to achieve adequate living conditions [15].

Alkire and Foster stated that the use of deprivation cut-offs for each dimension is more accurate, because the measurement of deprivation is easier than the measurement of achievements [4]. Therefore, the Alkire and Foster method is currently used to calculate the Multidimensional Poverty Index (MPI), which is based on the deprivations of households [13].

The third step of multidimensional methods is the weighting of deprivation factors, that influence who is identified as poor. Thus, it is valid to give equal importance to all of the deprivation factors [1] or to establish different weights according to the country context and reality [4].

It is important to establish methods to weight the identified dimensions when using these measurements. The weighting of dimensions allows the determination of how each dimension contributes to well-being and if it is possible to substitute one dimension for another, especially when there is no information available [1,34].

Previous researches have shown that the fuzzy theory has also been used to define multidimensional fuzzy poverty measures. Cerioli and Zani [21] indicate that if the transition from poverty to non-poverty is a gradual process, then the fuzzy theory captures many characteristics of standard of living, and represents the different degree to which each individual may be considered as poor [16,21,22]. Also, the fuzzy supplementary is a measure based on dimensions of durable goods and considers the dynamic concept of poverty [17]. The fuzzy set approach uses a membership aggregated function to measure different levels of deprivation factors [1,21].

3.2.3 Comparison of Multidimensional and Unidimensional Measures

The use of multidimensional methods leads to two kinds of errors in identifying people as poor. The first one occurs when the income of a person is low, but the individual's other deprivations are above the cut-off defined for selected well-being dimensions. The second

occurs when income is high, but people fall below thresholds of the selected well-being dimensions. Both are errors in which poor people are not identified correctly [2].

Acharya and Roemer explain that there is a conflict when unidimensional and multidimensional approaches are combined within aggregated measures. This is especially true when it is costly to collect information for each well-being dimension of each individual, or when no information has been collected at all [2].

Bader et al. consider that the monetary measure does not capture all the deprivations associated with gender, ethnic minorities, and others. If these deprivations are identified and quantified, the multidimensional measurement will aggregate them within an aggregated measure [13].

Additionally, if a household has enough income to fulfill its basic needs, it is not possible to determine the consumption behavior of the household, due to the impossibility to observe the individual's ability to transform income into achievements. Moreover, Golgher [25] establishes that households with similar income have diverse deprivation levels in other dimensions. Hence, the multidimensional approach allows the capturing of the effective ability of the household to achieve goods and services, especially those which improve living standards [13,25].

This result supports the fact that households cannot face different levels of deprivation in many dimensions, even though they have enough income resources. The multidimensional approach consolidates the appropriate indicators to establish a closer idea of the household's real situation. Therefore, it is necessary to have updated household information in order to determine the dimensions, indicators and weights that the multidimensional approach requires.

3.3 Methods of Counting People

This section points out some problems encountered in the literature review focused on limitations of these data sources based on methods of counting people.

The literature review shows that unidimensional and multidimensional measures are based on data of household surveys or censuses. As mentioned above, a household is defined as the unit of measurement of poverty, because the resources (including income) are shared in equal terms by all its members [26]. Official household surveys and censuses are the principal data source for accessing household data, which is stored in official institution databases [9].

The first limitation is that censuses become static in time and do not reflect the new needs of the population. In addition, surveys complement census data, but they still are not updated household data [9]. The second limitation relates to the resistance of household members to provide information when household data is collected. This implies that incomplete information is collected by surveys [15]. The third limitation is that surveys exclude people who are homeless or live in collective houses [15]. Therefore, data will not exist for those people and will exclude them from policies to reduce poverty. The fourth problem is that the door-to-door visitation method implies that the data remains the same until the next visit [30]. In this case, the study of Stampini et al. suggests that the lack of data induces policy makers to assume that poverty has defined characteristics due to its geographical location, for example, rural areas have chronic poverty while urban areas have moderate poverty [41].

Thus, as it is necessary to establish accurate multidimensional measures of poverty, the lack of household data and the reduction of frequency to collect it are problems to be solved in order to obtain a more comprehensive situation of poverty.

The World Bank considers these problems as a priority; hence, it is necessary to invest in data collection. It is necessary to generate and obtain more data to compare poverty across time, for all households and for a multidimensional view [45].

However, some countries do not even have household income data because their official surveys do not include this variable in their collection data process [26]. The lack of this variable provokes limitations in poverty analysis, considering the unidimensional approach.

On the other hand, lack of data in the multidimensional approach limits the selection of dimensions and does not guarantee that the household situation is adequate to the standard of life [14].

Moreover, some studies suggest that alternative methods are required to collect data concerning people in poverty, obtain complete and precise data of household characteristics, and reduce time and costs required to obtain and produce this information [9,45,46]. Alkire explains that collecting data of non-monetary dimensions is more accurate; it is not linked to geographic locations and can be focused on certain target population groups, like children, elders and women [3].

3.3.1 Prediction or Simulation Methods

Prediction or simulation methods are useful to estimate and complete data of households. These methods use other types of data, which infer a certain household characteristic within the measurement of poverty [30]. This section presents a review of recent literature on prediction or simulation methods.

The study of Harttgen and Vollmer provides an approach to simulate household income. An asset index was constructed as a proxy for household income, because asset data is collected in official surveys, and does not suffer long-term fluctuations [26].

The model introduced by Mathiassen to estimate poverty measures has the advantage that it uses light surveys, which supplement general household budget surveys. This model obtains consumption proxies with good confidence levels, low costs and short amount of processing data time [30].

The research of Zedini and Belhadj applies possibility theory, which is considered a fuzzy restriction, to minimize the uncertainty of poverty measures, especially when there is incomplete income data [46].

Azadeh et al. propose using living standard measures to predict the expenditures of a household. This study uses an artificial neural network to establish the relationships between expenditure/income and certain living standard measures [12].

3.3.2 Using Alternative Data Sources

A series of studies has indicated that the use of telephone records permits the analysis of certain characteristics, allowing the establishment of the degree of poverty of households by determining networks of communication between users, and similar socio-economic characteristics. This method establishes behavior patterns amongst users, by assembling a virtual communication network. Thus, it is possible to correlate the way in which users communicate and whom they do it with, to poverty levels established for the user residence area [18,32,35,40,42].

Studies are performed using geospatial data or satellite images. Similarities can be established between the population that lives in a given area and the population in areas already defined as poor. Thus, it can be inferred that the population in a certain area has an established poverty level [23,24,42].

These new repositories are considered big data. Therefore, it requires strategies to handle and analyze them. One of these strategies is data mining, which is used to analyze and extract useful information from these big data repositories. Its methods are improved to determine the compatibility of data [11]. Weng and

Young [44] and Njuguna and McSharry [32] indicate that the use of big data increases the accuracy in handling this type of massive datasets, offers an advantage in obtaining timely estimates of household development, and facilitates a continuous monitoring of the application of public policies.

The use of these strategies could reduce gaps in understanding a household's lifecycle, because it could make it possible to map diverse kind of data, like economic status or health of the members. Hence, the prediction of future situations could be possible in order to reduce the risk of households falling in poverty [27].

There is an evolution in the combination and use of data sources: first, the conventional censuses, and secondly, surveys and censuses based on administrative records and sample surveys. The final challenge is to combine censuses, surveys, administrative registers, and other aforementioned data sources [9]. The next step is the use of alternative measures needed to complement data collected between censuses [42].

Then, data culture is established as Aragona and Zindato explain. The data is collected the moment it is generated, and it is used to produce information immediately. Moreover, there is data resulting from the interaction of people with the institution that gives a specific service. Currently, data is automated and unconscious, and it results in the use of unobtrusive methods, which collect data from households or individuals who are not aware of being studied [9]. Additionally, real-time data could reduce delays in making decisions in order to minimize the impact on household situations [27].

4. DISCUSSION

Our review evidences diverse methods to measure poverty through different approaches. In unidimensional approach, poverty methods are widely used today because of the facility to obtain household income data. Moreover, income is considered a variable that aggregates the individual's capabilities in achieving goods and services in order to improve household living conditions. Multidimensional poverty methods require a complex structure to obtain data in a specific dimension. Additionally, they require an analysis to select dimensions, indicators and weights that will reflect the household's well-being.

The review also shows the evolution in collecting household data. The door-to-door censuses and household surveys are the principal data sources, and their data are stored in official repositories. However, the static characteristic of those data sources results in not updated data of households over time. This issue has significant relevance to the multidimensional approach when household data is not available or updated for a specific dimension. This issue is usually explained because using door-to-door methods is an expensive approach. As a result, there are limitations in choosing dimensions to calculate multidimensional poverty measures, because it is not possible to define a dimension that contributes to the establishment of an accurate household well-being.

As the authors noted earlier, additional work is necessary to face these limitations. The selected publications in this paper show how the use of other alternatives of data sources, which generate data in less time and cost, can be applied to infer household characteristics. Therefore, these inferred characteristics can be used to calculate poverty measures.

Hence, alternative data sources face the problem of lack of data, especially when official data sources do not collect specific data that can be considered valuable in the measurement of multidimensional poverty. Within the digital culture, alternative data sources are accepted and used for research purposes. These data sources are constantly generated because everyone generates a digital thread of his or her activities. Therefore, behaviors and

patterns could be established according to the individual daily activities.

There are publications in which mobile service operators have made their data available to the scientific community in order to analyze and determine its use in measuring poverty. The use of estimating poverty methods depends on the selection of variables in the construction of the Multidimensional Poverty Index or the Human Development Index. It is important to determine if available data can be related to these measures in order to achieve a correct measurement.

In recent years, poverty multidimensionality forces the search for new methodologies to identify, replace and complete missing information. Therefore, other data sources can be included within the measurement of multidimensional poverty indexes.

Proposing a new framework to infer data of dimensions and calculate a multidimensional poverty index could be possible thanks to the constant generation of data. The challenge is to establish the correct dimensions and inferences to calculate poverty, in a way that obtaining data and inputting it for the framework could be permanent and easy.

5. CONCLUSIONS

The results of this literature review show the mechanisms used to measure poverty over time. The methods are used in unidimensional and multidimensional poverty approaches.

On the unidimensional approach, head count ratio and poverty gap measure the amount of necessary resources for the whole country population to reach the poverty line. The use of a single variable, like income or consumption, is due to the easy way in which data is obtained.

On the other hand, measures of the multidimensional approach include the Human Development Index, the Townsend deprivation index, the Multidimensional Poverty Index and multidimensional fuzzy poverty measures, which require the selection of relevant dimensions, the design of indicators, and the establishment of weighting procedures for dimensions.

The use of multiple variables implies a complex procedure in order to obtain data of each individual for each dimension. This is especially difficult when data is not collected or does not exist.

The importance of the multidimensional approach is based on the concept of multifaceted characteristics of poverty. Therefore, it is necessary to establish additional studies to understand the use of alternative data sources to acquire and complete household data, more thoroughly. Hence, the construction of multidimensional poverty measures will not be limited to the lack of data of some dimensions.

This study explains the limitations of door-to-door censuses and surveys due to their static and high cost features in collecting household data. Therefore, this literature review shows some potential advantages in using alternative methods to collect household data. However, it is necessary to adopt new conceptualizations in the use of other data sources.

This review shows that it is possible to infer household situations over time using alternative data sources, especially studying the data that members of the household are generating daily. The authors present information on prediction or simulation methods that enable the management of daily data and estimate the variation of household characteristics over time.

This paper addresses the need for the inclusion of alternative data sources that opens the possibilities to consider that the lack of data should not be a limitation in the design of a multidimensional poverty measure.

Nevertheless, it is important to consider the possible combination of official data sources with alternative data sources, which would

allow the update of the first ones permanently. It is necessary to establish new methods to combine institutional databases and estimated inferences of household characteristics based on alternative data sources.

This combination could reduce costs and time, in order to acquire updated household data and promote faster definition of public poverty reduction policies.

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7. REFERENCES

- [1] Rolf Aaberge and Andrea Brandolini. 2015. *Multidimensional poverty and inequality* (1st ed.). Elsevier B.V. DOI:https://doi.org/10.1016/B978-0-444-59428-0.00004-7
- [2] Avidit Acharya and John E. Roemer. 2015. Multidimensional poverty with missing attributes. *Econ Lett* 130, (2015), 51–55. DOI:https://doi.org/10.1016/j.econlet.2015.02.033
- [3] Sabina Alkire. 2017. Measuring Chronic Multidimensional Poverty. *J Policy Model* (2017). DOI:https://doi.org/10.1016/j.jpolmod.2017.05.020
- [4] Sabina Alkire and James Foster. 2011. Understandings and misunderstandings of multidimensional poverty measurement. *J Econ Inequal* 9, 2 (2011), 289–314. DOI:https://doi.org/10.1007/s10888-011-9181-4
- [5] Sabina Alkire and James Foster. 2011. Counting and multidimensional poverty measurement. *J Public Econ* 95, 7–8 (2011), 476–487. DOI:https://doi.org/10.1016/j.jpubeco.2010.11.006
- [6] Sudhir Anand and Amartya Sen. 1997. Concepts of Human Development and Poverty: A Multidimensional Perspective. *Poverty and Human Development: Human Development Papers*, 1–20.
- [7] Roberto Angulo, Yadira D áz, and Renata Pardo. 2016. The Colombian Multidimensional Poverty Index: Measuring Poverty in a Public Policy Context. *Soc Indic Res* 127, 1 (2016). DOI:https://doi.org/10.1007/s11205-015-0964-z
- [8] Paola Annoni, Rainer Bruggemann, and Lars Carlsen. 2015. A multidimensional view on poverty in the European Union by partial order theory. *J Appl Stat* 42, 3 (2015), 535–554. DOI:https://doi.org/10.1080/02664763.2014.978269
- [9] Biagio Aragona and Donatella Zindato. 2016. Counting people in the data revolution era: challenges and opportunities for population censuses*. *Int Rev Sociol* 26, 3 (2016), 367–385. DOI:https://doi.org/10.1080/03906701.2016.1244926
- [10] Oihana Aristondo and Mariateresa Ciommi. 2016. International Journal of Approximate Reasoning The decompositions of rank-dependent poverty measures using ordered weighted averaging operators. *Int J Approx Reason* 76, (2016), 47–62. DOI:https://doi.org/10.1016/j.ijar.2016.04.008
- [11] Veli Atalay, Suleyman Ustun, and Selin Bulbul. 2013. The Determination of Socio-economic Factors Affecting Student Success by Data Mining Methods. *2013 12th Int Conf Mach Learn Appl* 2, (2013), 540–542. DOI:https://doi.org/10.1109/ICMLA.2013.174
- [12] Ali Azadeh, Samaneh Davarzani, Azadeh Arjmand, and Mansoureh Khakestani. 2016. Improved prediction of household expenditure by living standard measures via a unique neural network: the case of Iran. *Int J Product Qual Manag* 17, 2 (2016), 142–182. DOI:https://doi.org/10.1504/IJPMQ.2016.074464
- [13] Christoph Bader, Sabin Bieri, Urs Wiesmann, and Andreas Heinimann. 2016. Differences Between Monetary and Multidimensional Poverty in the Lao PDR: Implications for Targeting of Poverty Reduction Policies and Interventions. *Poverty and Public Policy* 8, 2 (2016), 171–197. DOI:https://doi.org/10.1002/pop4.140
- [14] Diego Battiston, Guillermo Cruces, Luis Felipe, Maria Ana, Lugo Maria, and Emma Santos. 2013. Income and Beyond: Multidimensional Poverty in Six Latin American Countries. *Soc Indic Res* 112, (2013), 291–314. DOI:https://doi.org/10.1007/s11205-013-0249-3
- [15] N. P Bellido, M. D. Jano, F. J. Lopez Ortega, M. P. Martin-Guzman, and M. I Toledo. 1998. The Measurement and Analysis of Poverty and Inequality: Analysis Application Poverty Spanish Conurbations. *Int Stat Rev* 66, 1 (1998), 115–131.
- [16] Gianni Betti, Bruno Cheli, Achille Lemmi, and Vijay Verma. 2008. The Fuzzy Set Approach to Multidimensional Poverty: the Case of Italy in the 1990s. In *Quantitative Approaches to Multidimensional Poverty Measurement*. Palgrave Macmillan, London, 30–48. DOI:https://doi.org/https://doi.org/10.1057/9780230582354_2
- [17] Gianni Betti, Antonella D’Agostino, and Laura Neri. 2002. Panel regression models for measuring multidimensional poverty dynamics. *Stat Methods Appl* 11, 3 (2002), 359–369. DOI:https://doi.org/10.1007/BF02509832
- [18] Joshua Blumenstock, Gabriel Cadamuro, and Robert On. 2015. Predicting poverty and wealth from mobile phone metadata. *Science* (80-) 350, 6264 (2015), 1073–1076. DOI:https://doi.org/10.1126/science.aac4420
- [19] Walter Bossert, Satya R. Chakravarty, and Conchita D’Ambrosio. 2013. Multidimensional Poverty and Material Deprivation with Discrete Data. *Rev Income Wealth* 59, 1 (2013), 29–43. DOI:https://doi.org/10.1111/j.1475-4991.2012.00519.x
- [20] Francois Bourguignon and Satya R Chakravarty. 2003. The measurement of multidimensional poverty. *J ofEconomic Inequal* 1, (2003), 25–49. DOI:https://doi.org/https://doi.org/10.1023/A:1023913831342
- [21] Andrea Cerioli and Sergio Zani. 1990. A Fuzzy Approach To The Measurement Of Poverty. (1990).
- [22] Amitava Chatterjee, Supratim Mukherjee, and Samarjit Kar. 2014. Poverty Level of Households: A Multidimensional Approach Based on Fuzzy Mathematics. *Fuzzy Inf Eng* 6, 4 (2014), 463–487. DOI:https://doi.org/10.1016/j.fiae.2015.01.005
- [23] Pranab Ranjan Choudhury and Manoj Kumar Behera. 2017. Using Administrative Data for Monitoring and Improving Land Policy and Governance in India. *Proc 10th Int Conf Theory Pract Electron Gov - ICEGOV ’17* (2017), 127–135. DOI:https://doi.org/10.1145/3047273.3047296
- [24] Timnit Gebru, Jonathan Krause, Yilun Wang, Duyun Chen, Jia Deng, Erez Lieberman Aiden, and Li Fei-Fei. 2017. Using Deep Learning and Google Street View to Estimate the Demographic Makeup of the US. 0, (2017). DOI:https://doi.org/10.1073/pnas.1700035114
- [25] Andre Golgher. 2016. Multidimensional poverty in urban Brazil: Income, assets and expenses. *Int J Soc Econ* 43, 1 (2016), 19–38. DOI:https://doi.org/10.1108/IJSE-06-2013-0140
- [26] Kenneth Harttgen and Sebastian Vollmer. 2013. Using an asset index to simulate household income. *Econ Lett* 121, 2 (2013), 257–262. DOI:https://doi.org/10.1016/j.econlet.2013.08.014
- [27] D. Helbing and S. Ballesti. 2011. From social data mining to forecasting Socio-Economic crises. *Eur Phys J Spec Top* 195, 1 (2011), 3–68. DOI:https://doi.org/10.1140/epjst/e2011-01401-8
- [28] Ronald Paul Hill and Bahram Adrangi. 1999. Global Poverty and The United Nations. *J Public Policy Mark* 18, 2 (1999), 135–146. Retrieved from http://www.jstor.org/stable/30000535
- [29] Barbara Kitchenham, O. Pearl Brereton, David Budgen, Mark Turner, John Bailey, and Stephen Linkman. 2009. Systematic literature reviews in software engineering - A systematic literature review. *Inf Softw Technol* 51, 1 (2009), 7–15. DOI:https://doi.org/10.1016/j.infsof.2008.09.009
- [30] Astrid Mathiassen. 2013. Testing Prediction Performance of Poverty

Models: Empirical Evidence from Uganda. *Rev Income Wealth* 59, 1 (2013), 91–112. DOI:<https://doi.org/10.1111/roiw.12007>

- [31] Kathryn M. Neckerman, Irwin Garfinkel, Julien O. Teitler, Jane Waldfogel, and Christopher Wimer. 2016. Beyond Income Poverty: Measuring Disadvantage in Terms of Material Hardship and Health. *Acad Pediatr* 16, 3 (2016), 52–59. DOI:<https://doi.org/10.1016/j.acap.2016.01.015>
- [32] Christopher Njuguna and Patrick McSharry. 2017. Constructing spatiotemporal poverty indices from big data. *J Bus Res* 70, (2017). DOI:<https://doi.org/10.1016/j.jbusres.2016.08.005>
- [33] Manap Abd Nurliyana, Zakaria Zalmiyah, and Hassan Rohayanti. 2017. Investigation of Poverty Indicators for Designing Case Representation to Determine Urban Poverty. *Int J Adv Soft Comput Its Appl* 9, 2 (2017).
- [34] Atika Pasha. 2017. Regional Perspectives on the Multidimensional Poverty Index. *World Dev* 94, June (2017), 268–285. DOI:<https://doi.org/10.1016/j.worlddev.2017.01.013>
- [35] Neeti Pokhriyal, Wen Dong, and Venu Govindaraju. 2015. Virtual Networks and Poverty Analysis in Senegal. *CoRR* (2015). Retrieved from <http://arxiv.org/abs/1506.03401>
- [36] Nicole Rippin. 2016. Multidimensional poverty in Germany: A capability approach. *Forum Soc Econ* 45, 2–3 (2016), 230–255. DOI:<https://doi.org/10.1080/07360932.2014.995199>
- [37] Maria Emma Santos. 2014. *Measuring Multidimensional Poverty in Latin American: previous experience and the way forward*.
- [38] Amartya Sen. 1973. Poverty: An Ordinal Approach to Measurement. *Econometrica* 44, 2 (1973), 219–231. Retrieved from <http://www.jstor.org/stable/1912718>
- [39] R. Sharath, S. Krishna Chaitanya, K. N. Nirupam, B. J. Sowmya, and K. G. Srinivasa. 2016. Data analytics to predict the income and economic hierarchy on Census data. *2016 Int Conf Comput Syst Inf Technol Sustain Solut CSITSS 2016* (2016), 249–254. DOI:<https://doi.org/10.1109/CSITSS.2016.7779366>
- [40] Christopher Smith-Clarke, Afra Mashhadi, and Licia Capra. 2014. Poverty on the Cheap: Estimating Poverty Maps Using Aggregated Mobile Communication Networks. *Proc SIGCHI Conf Hum Factors Comput Syst* (2014), 511–520. DOI:<https://doi.org/10.1145/2556288.2557358>
- [41] Marco Stampini, Marcos Robles, Mayra Sáenz, Pablo Ibarrarán, and Nadin Medellín. 2016. Poverty, vulnerability, and the middle class in Latin America. *Lat Am Econ Rev* 25, 1 (December 2016), 4. DOI:<https://doi.org/10.1007/s40503-016-0034-1>
- [42] Jessica E. Steele, Pål Roe Sundsøy, Carla Pezzulo, Victor A. Alegana, Tomas J. Bird, Joshua Blumenstock, Johannes Bjelland, Kenth Engø-Monsen, Yves Alexandre De Montjoye, Asif M. Iqbal, Khandakar N. Hadiuzzaman, Xin Lu, Erik Wetter, Andrew J. Tatem, and Linus Bengtsson. 2017. Mapping poverty using mobile phone and satellite data. *J R Soc Interface* 14, 127 (2017). DOI:<https://doi.org/10.1098/rsif.2016.0690>
- [43] Vijay Verma, Gianni Betti, and Francesca Gagliardi. 2017. Fuzzy Measures of Longitudinal Poverty in a Comparative Perspective. *Soc Indic Res* 130, 2 (2017), 435–454. DOI:<https://doi.org/10.1007/s11205-015-1194-0>
- [44] Jiaying Weng and Derek S. Young. 2017. Some dimension reduction strategies for the analysis of survey data. *J Big Data* 4, 1 (2017), 1–19. DOI:<https://doi.org/10.1186/s40537-017-0103-6>
- [45] World Bank Publications. 2018. *Poverty and Shared Prosperity 2018: Piecing Together the Poverty Puzzle*. Washington, DC. DOI:<https://doi.org/10.1596/978-1-4648-1330-6>
- [46] Asma Zedini and Besma Belhadj. 2015. Modeling uncertainty in monetary poverty : A possibility-based approach. *Fuzzy Sets Syst* 1, (2015), 1–14. DOI:<https://doi.org/10.1016/j.fss.2015.11.009>