MEASURING POVERTY USING FUZZY SETS

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National Centre for Social and Economic Modelling
• Faculty of Management • University of Canberra •

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Abstract

During the past few decades, many attempts have been made to find a suitable way of measuring poverty. The traditional approaches usually assess the poverty status of an individual by resorting to a unique indicator of resources, such income or expenditure. So the poor are generally regarded as those individuals or households whose incomes or expenditures fall below a certain amount of money, called the poverty line. However, this procedure contains some drawbacks. In fact, each indicator reflects only a special aspect of poverty.

Given the limitations related to measures of poverty based on a single indicator, multivariate methods have been explored. With such techniques, various aspects of poverty can be included and summarised in a single number. This leads to a much wider concept of poverty, reflecting dimensions other than just the monetary one. A major advantage of a multidimensional measure of poverty over the traditional ones is that it not only takes account of the material situation of individuals but it also captures their general living conditions. Despite the limitations of a one-dimensional framework, there is no consensus on how poverty should be measured.

Nevertheless, it is generally agreed that the transition from a state of complete deprivation to a comfortable situation happens rather gradually. One way of accounting for that characteristic is to take advantage of the tools provided by the theory of fuzzy sets. It seems particularly appropriate for modelling vague concepts, such as poverty. The aim of this paper is to assess living conditions in Switzerland using fuzzy sets. The results show that the use of several poverty indicators helps in giving a more complete picture of poverty than the sole use of more common indicators such as disposable income or expenditure.

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General caveat

NATSEM research findings are generally based on estimated characteristics of the population. Such estimates are usually derived from the application of microsimulation modelling techniques to microdata based on sample surveys.

These estimates may be different from the actual characteristics of the population because of sampling and nonsampling errors in the microdata and because of the assumptions underlying the modelling techniques.

The microdata do not contain any information that enables identification of the individuals or families to which they refer.

Contents

1 Introduction

During the past few decades, many attempts have been made to find a suitable way of measuring poverty. The first step is obviously to define poverty. This leads to the poor being identified. The next step is to aggregate the information on each individual or household, leading to an index number that summarises the extent of poverty for the whole population. Initially this paper focuses on the problem of identification.

There are, of course, many ways of defining poverty. For instance, in the absolute approach, some basic needs are taken as the poverty threshold (see, for example, Booth 1969, Rowntree 1901, Orshanski 1965 or Watts 1967). An alternative approach is to define the poor relatively, by comparing the situation of each individual with the standard of living prevailing at a certain point of time in a given country (see Townsend 1979). Yet another approach, the subjective approach, lets individuals evaluate their own situation (see Goedhart et al. 1977 and van Praag 1971).

These approaches have in common the fact that they all assess the poverty status of an individual or a household by resorting to a unique indicator of resources — income or expenditure, for example. So the poor are generally regarded as those individuals or households whose incomes or expenditures fall below a certain amount of money, called the poverty line. However, this procedure contains some drawbacks. In fact, each indicator reflects only a special aspect of poverty. For instance, if income is chosen as the relevant indicator for evaluating whether a person is poor, it is assumed that income gives an idea about the opportunities that person has to meet some previously defined basic needs, but it is not known how the income is finally spent. Moreover, income alone does not tell very much about an individual's living conditions. For example, a relatively low level of income could be more than compensated for by the fact that its recipient owns a house.

Likewise, the use of expenditures as the indicator of resources is not entirely satisfactory. Expenditures allow poverty to be measured from a standard of living standpoint. But, again, people with lower consumption expenditures should not automatically be considered poorer, because it can be the result of selecting cheaper goods and services, or simply of not participating in certain activities.

Among the authors who advocate the use of alternative indicators of resources that better reflect the living conditions of individuals, Travers and Richardson (1993) propose the concept of *full income*. In addition to the elements usually contained in the definition of income, full income incorporates further components of wellbeing, such as health or time. Full income is obtained by imputing a money value for those components, based on the market opportunity cost or the price individuals would have to pay for buying an equivalent service. Nevertheless, Travers and Richardson recommend the use of direct measures of poverty along with full income. These measures are achieved by asking the individuals how they evaluate their own situation in terms of food, clothing, shelter or transport, for example.

Given the limitations related to measures of poverty based on a single indicator, *multivariate* methods should be explored. With such methods, various aspects of poverty can be included and summarised in a single number. This leads to a much wider concept of poverty, reflecting other dimensions than just the monetary one. A major advantage of a multidimensional measure of poverty over the traditional ones is that it not only takes account of the material situation of individuals but it also captures their general living conditions. In addition, according to Whelan (1993), a global index of poverty based on a set of deprivation indicators seems more appropriate than indices based on only income or expenditure to assess a situation of permanent poverty. Such an index should ideally take account of the basic needs, including food, clothing, housing and household equipment. It might also contain information on

other variables that are mostly related to social life and sometimes exerting some constraint on it. Working conditions, leisure, health, education, environment, family and social activities are some examples of these kinds of variables.

Some authors have tried to emphasise other aspects of poverty than just the monetary ones when measuring poverty. For example, Townsend (1979) selected 60 indicators that were supposed to summarise the common activities in society. Then he derived a deprivation index based on twelve of the items. Another interesting approach was proposed by Mack and Lansley (1985). They developed and refined the theoretical and empirical work of Townsend and proposed a measure of poverty that is based on the social perception of needs, which means that those items classified as necessary by more than 50 per cent of the population are defined as necessities. Halleröd (1994) suggested a similar approach except that all the items are retained as necessities to some extent in the poverty measure. Each item is given a weight based on the proportion of the population that regards it as a necessity.

In a one-dimensional framework, the current practice for measuring poverty is based on the assumption that the poor can be identified by determining a poverty line. Nevertheless, as can easily be imagined and as the multiple proposals found in the literature seem to suggest, it is difficult to achieve wide consensus on the setting of such a limit. As pointed out by Cerioli and Zani (1990) and by Cheli et al. (1994), among others, the problem is in part due to the fact that a sharp division of the total population between poor and non-poor is unrealistic. Except for some purposes of economic policy, it cannot reasonably be maintained that, of two individuals or households with equivalent incomes or expenditures differing only by a few cents, but on different sides of the poverty line, one should be considered poor and the other not poor. On the contrary, it is generally agreed that the transition from a state of complete deprivation to a comfortable situation happens rather

gradually. Mack and Lansley (1985, p. 41) pointed out that it is likely that there is a continuum of living standards from the poor to the rich that makes any cutoff point somewhat arbitrary. One way of taking this into account is to take advantage of the tools provided by the theory of fuzzy sets. It seems particularly suitable for modelling vague concepts such as poverty. This paper agrees with those authors who insist that, if a notion is not exact by nature, the degree of ambiguity it carries should not be removed (see Basu 1987 and Ok 1995, 1996).

Several recent studies have proposed a multidimensional measure of poverty based on the theory of fuzzy sets. Cerioli and Zani used this method to evaluate living conditions in an Italian county. Their work has been followed by others who extended some theoretical aspects (see Cheli and Lemmi 1995 or Chiappero-Martinetti 1994). The applications that have been achieved so far concern mainly Italy (see Dagum, Gambassi and Lemmi 1992 and Pannuzi and Quaranta 1995) or Poland (see Cheli et al. 1994). In this paper the technique suggested by Cerioli and Zani is used to assess living conditions in Switzerland. Chapter 2 presents different methods of measuring poverty. After presenting the fuzzy approach, the paper briefly considers two alternative methods based on a single indicator of resources: the *headcount ratio* and *stochastic dominance*. Chapter 3 provides a general analysis of poverty in Switzerland and chapter 4 presents some decomposition of the multidimensional index of poverty, before comparing it with the other approaches.

2 Methods of measuring poverty

2.1 Fuzzy index of poverty

In his work on fuzzy sets, Zadeh (1965, p. 338) mentions that some ‘classes of objects encountered … do not have precisely defined criteria of membership’. They do not constitute classes or sets in the usual way

in mathematics. The concept of fuzzy sets provides an ideal framework to deal with problems in which there does not exist a definite criterion for discerning what elements belong or do not belong to a given set. This is thus a very attractive notion for solving the problem of identifying the poor. With this kind of approach, it is not necessary to specify a poverty line. This section of chapter 2 gives some definitions and sets out the various steps to determine the degree to which each individual belongs to the set of poverty and the resulting poverty index.

Definition of a fuzzy set

Let X be a set and x some element of X. A fuzzy subset A of X is defined as the set of couples:

(1) $$A = \{x, \mu_A(x)\}$$

for all $x \in X$, and where μ_A, called a membership function, is an application from X in [0,1]. In other words, the fuzzy subset A of X is characterised by a membership function $\mu_A(x)$ associating a real number in the interval [0,1] to each point of X. The value $\mu_A(x)$ represents the degree of belonging of x to A. If A is an ordinary set, its membership function can then take only the values 0 and 1. In that case:

(2) $$\mu_A(x) = \begin{cases} 1, & \text{if} \quad x \in A \\ 0, & \text{if} \quad x \notin A \end{cases}$$

Similarly, when A is a fuzzy set, $\mu_A(x) = 1$ if x belongs entirely to A, whereas $\mu_A(x) = 0$ if x is not a member of A. On the other hand, if x belongs only partly to A, then $0 < \mu_A < 1$. The degree of membership of x to A rises as the values of $\mu_A(x)$ get closer to 1.

Because the concept of poverty is not as sharp as it is sometimes assumed to be, the same procedure can be used to define the fuzzy set of the poor. Let $N = \{1, \ldots, n\}$ be the set of individuals or households in a population and P be the fuzzy subset of the poor, defined as follows:

(3) $$P = \{i, \mu_P(i)\}$$

with $i = 1,\ldots,n$ and where $\mu_P(i)$ represents the degree of membership of each individual i to the fuzzy subset of the poor. The membership function can take one of the following values:

$$(4) \qquad \begin{cases} \mu_P(i) = 0 \\ \mu_P(i) = 1 \\ 0 < \mu_p(i) < 1 \end{cases}$$

depending on whether an individual is absolutely not poor, belongs completely to the set of poor or is only poor to a certain extent.

Membership functions

Given the multidimensional nature of poverty, it is necessary to assess the degree of membership of each individual or household to the fuzzy subset of poor from a set of indicators of living conditions, both qualitative and quantitative. Each variable chosen refers to a special aspect of poverty, either rendering the privation of a given item or of a certain activity or representing a symptom of poverty. The principal issue is then to select an appropriate membership function for each indicator of deprivation. At least three categories of variables are distinguished — namely, dichotomic, polytomic or continuous. For each of these categories, the membership function can be expressed under a general form.

Call $\xi = [\xi_1,\ldots,\xi_k]$ the set of indicators of living conditions. Let Ξ_j be the subset of individuals or households undergoing some privation according to indicator ξ_j, with $j = 1,\ldots,k$. The simplest membership function is the one associated to a dichotomic variable, typically indicating the possession of durable goods. In this case the subset Ξ of the population is not fuzzy at all since the membership function can be written as:

$$(5) \qquad \mu_{\Xi_j}(i) = \begin{cases} 1, & \text{if} \quad \xi_{ij} = 0 \\ 0, & \text{if} \quad \xi_{ij} = 1 \end{cases}$$

where ξ_{ij} takes a zero value when individual i does not own good j and a unit value in the opposite case. In other words, individuals belong to the subset of deprived people, according to indicator ξ_j unless they are equipped with the good in question.

In a multidimensional analysis of poverty, sometimes use is also made of qualitative variables, presenting several possible values, each of them corresponding to a certain degree of privation. Assume that those modalities can be ranked by increasing risk of poverty. An example is given by a variable showing individuals' subjective evaluations of their own situations. The possible values could then be *very good*, *fairly good*, *average*, *fairly bad* and *very bad*. In a general framework with m modalities, indicator ξ_j takes its values in the set $\{\xi_j^{(1)},\ldots,\xi_j^{(m)}\}$. With the hypothesis that they are ordered so that an increasing value of the upper index denotes a worsening in the privation status[1] and if a score $\psi_j^{(l)}$ is associated with each modality $\xi_j^{(l)}$, with $l=1,\ldots m$, the following relationship between the scores can be observed:

$$\psi_j^{(1)} < \cdots < \psi_j^{(l)} < \cdots < \psi_j^{(m)}. \tag{6}$$

In most of the cases, the first m integers are simply adopted as the ordinal scale for defining these scores. Thus:

$$\psi_j^{(l)} = l \tag{7}$$

with $l=1,\ldots,m$. This kind of definition is particularly suited for situations in which the categories represented by the different modalities are equally spaced[2]. Given the ordinal nature of the qualitative variable ξ_j, it is possible to find a modality corresponding to a situation favourable enough to exclude poverty. On the other hand, it is possible to choose a modality associated with such bad living conditions that

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1 This is the same kind of specification as used by Cerioli and Zani (1990, pp. 275–6), but while they implicitly rank the modalities by decreasing risk of poverty, this study does the opposite.

2 Obviously, other assumptions on the ordinal scale lead to a different set of scores.

poverty cannot be denied. If $\psi_j^{\min}$ and $\psi_j^{\max}$ are the scores corresponding to those limits, the membership function as proposed by Cerioli and Zani can be expressed as:

$$\mu_{\Xi_j}(i) = \begin{cases} 0 & \text{if} \quad \psi_{ij} < \psi_j^{\min} \\ \dfrac{\psi_{ij} - \psi_j^{\min}}{\psi_j^{\max} - \psi_j^{\min}} & \text{if} \quad \psi_j^{\min} \le \psi_{ij} \le \psi_j^{\max} \\ 1 & \text{if} \quad \psi_{\mathrm{ij}} > \psi_j^{\max} \end{cases} \tag{8}$$

where ψ_{ij} is the score for individual i ensuing from indicator ξ_j. With this specification, the membership function increases linearly as the risk of poverty rises.

Finally, continuous variables are found among living conditions indicators. The most widely used variables of this kind in traditional studies on poverty are income or expenditure. In the literature, some authors provide an alternative to the problem of setting a unique, clear-cut poverty line. For instance, Kakwani (1995) proposes a method that takes into account the uncertainty about the exact value of the poverty threshold. On the other hand, Atkinson (1987) and Foster and Shorrocks (1988a) suggest an ordinal approach related to stochastic dominance. Those methods have in common the fact that they establish an interval supposed to contain the real poverty line, instead of setting the poverty line itself. In a different context, Cerioli and Zani propose the setting of two limits. The first one, noted $\xi_j^{\min}$, refers to the value of the chosen indicator of poverty defining some absolute poverty threshold below which a given individual or household can without any hesitation be considered poor. The second limit, noted $\xi_j^{\max}$, represents the value of the variable beyond which an individual can certainly be regarded as out of poverty[3]. For those values of the variable included between the two

[3] The determination of the lower and upper bounds of such an interval is not always straightforward, because those limits generally depend on the socio-economic context and on the specific characteristics of each indicator of privation.

limits, the membership function must take its values in the interval [0,1]. Furthermore, a natural requirement for this function is that it be continuous and decreasing, at least for those indicators for which an increase in value means an improvement of wellbeing. Cerioli and Zani define the following membership function:

$$\mu_{\Xi_j}(i) = \begin{cases} 1 & \text{if} \quad 0 \le \xi_{ij} < \xi_j^{\min} \\ \dfrac{\xi_j^{\max} - \xi_{ij}}{\xi_j^{\max} - \xi_j^{\min}} & \text{if} \quad \xi_{ij} \in [\xi_j^{\min}, \xi_j^{\max}] \\ 0 & \text{if} \quad \xi_{ij} > \xi_j^{\max} \end{cases} \tag{9}$$

By doing so, they assume that the risk of poverty varies linearly between the two limits $\xi_j^{\min}$ and $\xi_j^{\max}$ (see Cerioli and Zani 1990).

The membership functions that have been defined so far are obviously not the only conceivable ones. Yet some forms are more desirable than others, because of their properties. Some authors propose an alternative way of defining the membership function in the case of qualitative polytomic and continuous indicators (see Cheli et al. 1994 and Cheli and Lemmi 1995). Cheli and Lemmi call their approach *totally fuzzy and relative*. The main improvement it brings, compared with equations 8 and 9, is that it does not require the setting of any limit, which is always arbitrary to a certain extent. In addition, their approach is closer to a relative concept of poverty, taking account of the general living conditions prevailing in the society, instead of comparing the situation of individuals to some absolute norm.

Cheli and Lemmi suggest the following membership function for a qualitative polytomic variable:

$$\mu_{\Xi_j}(i) = \begin{cases} 0 & \text{if} \quad \xi_{\mathrm{ij}} = \xi_j^{(1)} \\ \mu_{\Xi_j}(\xi_j^{(l-1)}) + \dfrac{F_j(\xi_j^{(l)}) - F_j(\xi_j^{(l-1)})}{1 - F_j(\xi_j^{(1)})} & \text{if} \quad \xi_{ij} = \xi_j^{(l)}, l = 2, \ldots, m \end{cases} \tag{10}$$

where $\mu_{\Xi_j}(\xi_j^{(l-1)})$ represents the degree of belonging to the set Ξ_j of an individual showing modality $l-1$ for indicator ξ_j. Moreover, F_j is the cumulative distribution function for variable ξ_j, the modalities being ranked by increasing risk of poverty. With this formulation, the membership function takes a zero value when the risk of poverty is at its minimum level and a unit value when it is at its maximum. Between the extremes, the degree of belonging of each individual to the subset of deprived people, according to indicator ξ_j, lies in the interval [0,1] and increases with the risk of poverty.

For continuous indicators of privation, Cheli and Lemmi propose one of the following membership functions:

(11) $$\mu_{\Xi_j}(i) = F_j(\xi_{ij})$$

or

(12) $$\mu_{\Xi_j}(i) = 1 - F_j(\xi_{ij})$$

depending on whether an increase in value of indicator ξ_j goes along with a higher or a lower risk of poverty, respectively. Here again, F_j represents the cumulative distribution function for indicator ξ_j. In the case of continuous variables, either it is given by the empirical distribution or it is derived from a suitable theoretical distribution, estimated on sample data (see, for example, Dagum et al. 1992). It should be noted that two income distributions, differing only in the levels of income, with one distribution obtained from the other by transferring the same amount to all the income recipients, would lead to the same degree of belonging to the set of poor for each individual. This is obviously due to the fact that Cheli and Lemmi suggest a relative approach for measuring poverty.

Nevertheless, although their formulation of a membership function for continuous variables seems very attractive, it is not recommended for a number of reasons. One reason is that the degrees of membership are

determined only by the relative position of each individual with respect to that of the remaining individuals. So only information on the percentage of individuals with a higher income than that of a given individual is used and no consideration is given to income levels or income gaps. This could result in the same sets of degrees of membership when considering two distributions, the first one having concentrated incomes and the second showing a great dispersion. It can be argued that it should be possible to differentiate between distributions with different characteristics. Another reason for being reluctant to use the totally fuzzy and relative approach will become apparent in the next subsection.

Aggregation of deprivation indicators

The preceding subsection covered how to define membership functions for various sorts of indicators. All individuals can thus have their degree of belonging to the subset of deprived people assessed according to each of the k deprivation indicators, considered separately. Now those k indicators need to be reduced to one dimension, in order to evaluate the degree of membership $\mu_P(i)$ of each individual i to the fuzzy subset of the poor P. Poverty is then regarded as an accumulation of deprivation situations. In other words, k fuzzy sets $\Xi_1, \Xi_2, \ldots, \Xi_k$ are defined over the set of individuals N. The problem is finding some function h of the degrees of belonging $\mu_{\Xi_j}(i)$ that transforms them and provides new degrees of membership. This gives the following relationship:

$$\mu_P(i) = h(\mu_{\Xi_1}(i), \mu_{\Xi_2}(i), \ldots, \mu_{\Xi_k}(i)) \tag{13}$$

There are of course many possibilities for defining function h. According to Chiappero-Martinetti (1994), such a function should lie somewhere between the minimum and maximum value of the degrees of membership and must allow interactions between the various indicators of deprivation. A convenient way of achieving this requirement is to make

use of a generalised weighted average as the aggregation operator. It is then possible to write h as:

$$h_\delta(\mu_{\Xi_1}(i),\ldots,\mu_{\Xi_k}(i)) = \left[\sum_{j=1}^{k} \omega_j (\mu_{\Xi_j}(i))^\delta\right]^{1/\delta} \tag{14}$$

where $\delta \neq 0$ is a parameter referring to the type of mean. For example, when $\delta \to 0$, a geometric mean is obtained, whereas when $\delta = -1$, h corresponds to a harmonic mean. In the case where $\delta = 1$, h reduces simply to an arithmetic mean. The ω_j on the right hand side of expression 14 represents the weight that should be attributed to indicator ξ_j in the aggregation process. Thus $\omega_j \geq 0, j = 1,\ldots k$ and $\sum_{j=1}^{k} \omega_j = 1$. It seems quite natural to introduce those weights because some indicators of deprivation are more important than others in assessing the living conditions of individuals. Cerioli and Zani define the degree of belonging of each individual to the fuzzy subset of the poor by taking the weighted arithmetic mean of their degrees of membership to the set of deprived people, according to the k indicators. So:

$$\mu_P(i) = \sum_{j=1}^{k} \omega_j \mu_{\Xi_j}(i) \tag{15}$$

The last issue concerns the choice of an appropriate system of weighting. This is probably one of the most important steps in determining the fuzzy index of poverty. Cerioli and Zani suggest the following specification for the weights:

$$\omega_j = \frac{\ln\left(1/\bar{\mu}_{\Xi_j}\right)}{\sum_{j=1}^{k} \ln\left(1/\bar{\mu}_{\Xi_j}\right)} \tag{16}$$

where $\bar{\mu}_{\Xi_j} = 1/n \sum_{i=1}^{n} \mu_{\Xi_j}(i)$ represents the fuzzy proportion of deprived individuals according to indicator ξ_j. In that way, the weights ω_j are an inverse function of the average deprivation level. The system of weights

presented in equation 16 gives more importance to those indicators of privation associated with less frequent symptoms of poverty. This can be justified by the fact that, in a relative definition of poverty, people have a stronger feeling of deprivation when they do not own a very widespread good.[4] In this context, the less individuals conform to the prevailing lifestyle, the more they should be considered poor. This ignores, of course, the case where individuals are deprived of a certain good or activity because of their preferences and by the consequence of a choice. This leads naturally to particular attention being paid to selecting relevant indicators that are supposed to summarise individual living conditions. The fact of not possessing a given good or of not participating to a certain activity does not necessarily have the same meaning for different groups of the population. On the other hand, the choice of the indicators of deprivation made by an external observer is always somewhat arbitrary. An alternative solution to this problem is the one proposed by Mack and Lansley (1985) or by Halleröd (1994), which consists of asking people what elements of life they regard as necessary.

Although the argument proposed by Cerioli and Zani for justifying the system of weighting given by equation 16 might seem attractive, it has some shortcomings. By making the weights dependent on the frequency of the symptoms of poverty, two problems are introduced. The first is that $\bar{\mu}$ does not have the same interpretation for different types of

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4 Obviously, any other system of weights satisfying the same properties could be chosen. An interesting interpretation of the weights selected by Cerioli and Zani can be brought to the fore by referring to the theory of information. The numerator in expression 16 can be related to a common information function (see Theil 1967, for example). Such a function takes its values in the interval $[0, \infty[$ and denotes in a way the degree of surprise associated with the occurrence of an event, given its a priori probability. So if some event is very likely to happen, people are less surprised when it does than if its probability is very low. Besides, the information function is decreasing in the value of the probability. If this interpretation is transposed to the weighting system, it means that the more some good is widespread in the population, the bigger the surprise of finding individuals who do not possess it. This justifies the relative importance given to such indicators of deprivation.

variables. For dichotomic variables, the meaning of $\bar{\mu}$ is straightforward. It represents the proportion of the population deprived according to a given indicator. The signification of $\bar{\mu}$ for continuous variables is not that clear. For this reason, the values of $\bar{\mu}$ are not fully comparable between variables of a different nature. Depending on the membership function chosen for continuous variables, it cannot necessarily be concluded that the intensity of deprivation is lower when the value for $\bar{\mu}$ is inferior to the one obtained for a dichotomic variable. A better solution could perhaps be to limit the aggregation process exclusively to variables of the same nature or to choose membership functions for continuous variables to give $\bar{\mu}$ the same interpretation as for dichotomic variables.[5]

There is a second reason why the weighting system proposed by Cerioli and Zani is open to criticism. Although the chosen specification is easily understandable and is based on a purely relative definition of poverty, it could be argued that some indicators are by nature more important than others when assessing living conditions. So when it is possible, the subjective evaluation of individuals on how important the different indicators are should be included. This can be achieved by adopting a similar approach to the one suggested by Mack and Lansley (1985) and Halleröd (1994). Obviously, the necessary information is not always available. In that case, the weighting system proposed by Cerioli and Zani seems a reasonable solution. However, as already mentioned, there are many other systems of weights satisfying the same properties. Consequently, it would be very useful to perform some sensitivity analysis to investigate how the results would be affected by a change in the weighting system.

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5 This could be achieved by selecting a single poverty line. Continuous variables would then be treated as dichotomic variables, individuals being regarded either as deprived or as not deprived, depending on which side of the poverty line they are. Obviously this would remove the fuzzy nature of the final poverty index.

As mentioned earlier, the totally fuzzy and relative approach recommended by Cheli and Lemmi contains an additional drawback, with respect to that suggested by Cerioli and Zani. It can be seen from expression 16 that, when the membership function is of the form 12 and the deprivation indicator is continuous, the fuzzy proportion of deprived individuals μ_{Ξ_j} does not provide any useful information. For instance, if income is taken as the indicator of privation and Dagum's theoretical distribution function is used, estimated over the sample, then the sample mean tends to coincide with the value corresponding to the median income. Theoretically the following equality can be verified:

$$E\left[\mu_{\Xi_j}(i)\right] = 1 - F_j(\overline{\xi}_j) = 0.5 \tag{17}$$

where $E()$ represents the expectation operator (see Cheli et al. 1994). In addition, if $F_j(\xi_{ij})$ is given by the empirical cumulative distribution function, then the degree of belonging of each individual i to the subset of deprived people is equal to:

$$\mu_{\Xi_j}(i) = 1 - \frac{i}{n} \tag{18}$$

provided that each income takes a different value. This is very often the case when sample data are used, especially if households are observed and equivalence scales are used to take into account differences in the needs of families with different compositions. Thus, if the sample size is large and if the average degree of membership to the fuzzy subset of deprived people is computed according to some indicator such as income, a value of 0.5 is obtained. Consequently, the use of a membership function defined as in 12 tends to always give the same absolute weight to indicators such as income or expenditure, although this is not necessarily realistic.

Fuzzy index of poverty

So far, the paper has described how to evaluate the degree of poverty of each individual or household (see equation 15). The next step is to define

a summary measure for the whole population. Cerioli and Zani construct a general index of poverty by averaging the individual membership functions:

$$FIP = \frac{1}{n}\sum_{i=1}^{n}\mu_P(i) \tag{19}$$

with $FIP \in [0,1]$. According to them, *FIP* 'represents the proportion of individuals "belonging" in a fuzzy sense to the poor subset' (Cerioli and Zani 1990, p. 282). Of course, $FIP = 0$ if and only if $\mu_P(i) = 0$ for each individual — that is, if there is no poverty — whatever indicator of privation is considered. On the other hand, the fuzzy index of poverty reaches its maximum value if and only if $\mu_P(i) = 1$ for each individual, which means conditions of extreme hardship for the whole population on all the indicators of deprivation. Nevertheless, both of these situations are rather unusual and in general $0 < FIP < 1$, index *FIP* being a monotonic increasing function of the degree of poverty of each individual. Therefore a deterioration of an individual's living conditions, other things remaining unchanged, results in an increase in *FIP*.

Finally, as Cerioli and Zani (p. 282) point out, '*FIP* provides a generalisation of traditional indices for the measurement of poverty'. Those indices include the Foster-Greer-Thorbecke class of poverty indices or Dalton-type poverty indices as special cases (see Foster, Greer and Thorbecke 1984 and Hagenaars 1987). In addition, the fuzzy index of poverty *FIP* belongs to the class of additively decomposable indices of poverty. This implies that, if the population is broken down into several subgroups, overall poverty should diminish as a result of a decrease in poverty in one of the subgroups, the situation remaining unchanged in the other subgroups. For this interesting property to apply, the various indicators of deprivation should receive the same weights across the whole population. Of course, separate weights could be calculated within each subgroup. This would indicate that the relative importance of each indicator is not the same in different subgroups. While some

arguments could be found for assigning different weights to each subgroup, this latter solution tends to complicate comparisons between the subgroups and is not in accordance with the totally relative definition of poverty.

2.2 Headcount ratio

The previous subsection presented a possible method for measuring poverty, when there are several indicators of deprivation. Most of the time, however, only a single indicator of resources can be relied on, such as income or expenditure. In such cases, the most popular approach consists of counting the number of poor individuals — that is, the number of persons who fall below a predetermined poverty line — and expressing that number as a percentage of the whole population. The resulting index of poverty is called the *headcount ratio*. More formally, it can be defined with the following expression:

$$H(x,z)=\frac{q}{n} \tag{20}$$

where $x \in \Re_+^n$ is the variable indicating the level of resources for the n individuals forming the total population, $z>0$ is the poverty line and q is the number of individuals whose indicator of resources takes a value inferior to the poverty line. The headcount ratio has a very simple interpretation. Obviously it takes its values in the interval [0,1], the bounds being reached in the extreme situations where there is no poverty at all and where the whole population is in poverty. Despite the simplicity and the wide use of this index, the headcount ratio has some drawbacks.

The headcount ratio takes into account only the number of individuals whose indicator of resources is inferior to the poverty line. This is not a desirable property. It would be better if it were able to distinguish between a situation where all the individuals are close to the poverty line

and another situation where, with the same number of poor people, the indicator of resources takes lower values for all the individuals. This feature is sometimes referred to in the literature as the monotonicity axiom, which is clearly violated by the headcount ratio, as pointed out by Sen (1976), for example. Another criticism of the headcount ratio made by Sen is that it does not satisfy the transfer axiom. This means that the headcount ratio is insensitive to transfers of resources from one individual to another, unless one of them crosses the poverty line as a result of the transfer. A suitable poverty index would be expected to show a decrease in poverty when a transfer occurs from a richer person to a poorer one, even if their relative ranking in the distribution remains unchanged.

In spite of the shortcomings associated with the use of the headcount ratio, this poverty index is still very popular in the applied studies on poverty because of its straightforward interpretation.

2.3 Stochastic dominance

When poverty is measured by resorting to a unique indicator of resources, such as income or expenditure, generally two major problems have to be solved. The first problem is the identification of the poor, which consists of selecting a suitable poverty line dividing the population into poor and not poor. The second problem relates to the aggregation of poverty, supposed to provide information about the percentage of the poor, the intensity of poverty and the inequality in the distribution of the indicator of resources among the poor. Obviously, it is extremely difficult to determine a poverty line and to choose a poverty index that is widely accepted. Moreover, when poverty is compared at two points in time, between countries or between subgroups of a population, different rankings of the elements of the comparison could be obtained, depending on where the poverty line is set and which index of poverty is used. These reflections have led some authors to investigate

alternative ways of measuring poverty and to propose ordinal approaches.

Atkinson (1987) insists that it is almost impossible to determine a unique poverty line because setting such a limit is always subject to controversy. However, suppose that the poverty line lies in a certain interval, given by $[z_{\min}, z_{\max}]$. Atkinson's approach consists then of examining whether the same ranking of poverty is obtained, whatever the value taken by the poverty line in the predefined range.

In the case of the headcount ratio, the technique proposed by Atkinson reduces to comparisons of cumulative distributions. Let x and y be two distributions for a given indicator of resources, with $f_X(t)$ and $f_Y(t)$ their respective probability density functions, the cumulative density functions being given by $F_X(t)$ and $F_Y(t)$. To compare these two distributions, their lower tails are contrasted by calculating the difference $\Delta F(t) = F_X(t) - F_Y(t)$. This amounts to comparing the percentage of the poor in the distributions. Atkinson states a first order stochastic dominance condition, saying that if $\Delta F(z) \leq 0$, whatever the value taken by the poverty line in the interval $[z_{\min}, z_{\max}]$, then it can be concluded that distribution y shows more poverty than distribution x, according to the headcount ratio. In other words, this means that the cumulative distribution function for y is always above that for x. The cumulative distribution can be represented graphically by displaying the cumulative percentage of population on the vertical axis and the indicator of resources on the horizontal axis. The resulting graph is referred to as the *incidence curve* in the literature. A dominance relationship between two distributions cannot take place if the incidence curves intersect on the predetermined interval.

Obviously the headcount ratio is not the only possible index of poverty that can be used for applying this method. In particular, the normalised income gap ratio can be used as a measure of poverty, multiplied by the

poverty line. The terms of the comparison are then the areas below the cumulative distribution functions. The following difference $\Delta\phi(z) = \int_0^z \Delta F(t)dt$ is now defined. Atkinson gives a second order stochastic dominance condition, stating that if $\Delta\phi(z) \leq 0$, whatever the value of the poverty line in the predetermined range, then it can be concluded that poverty is higher in distribution y than in distribution x. It can be proven that the first order stochastic dominance implies the second order stochastic dominance, but the converse is not true. Consequently, when the incidence curves for two distributions intersect, first order stochastic dominance is excluded, but not necessarily second order stochastic dominance. Again, the second order stochastic dominance can be represented graphically by displaying the areas below the incidence curve against the indicator of resources. The resulting graph is called the *poverty deficit curve*.

The preceding paragraphs have shown how to eliminate, at least in part, the ambiguity concerning the ranking of distributions when there is an uncertainty about the level of the poverty line. Another question is whether the ranking of the distributions remains unchanged whatever index of poverty is chosen. Of course this does not always occur. Nevertheless, some authors, such as Atkinson (1987), Foster and Shorrocks (1998b) and Jenkins and Lambert (1997), investigate stochastic dominance conditions that are valid for a wide range of indices.

When poverty is measured by resorting to a unique indicator of resources, such as income or expenditure, stochastic dominance is considered to be more efficient and powerful than single indices. In fact, when a dominance relationship can be proven between two distributions, then their ranking is valid for a wide range of poverty lines and of poverty indices (see, for example, Atkinson 1987 or Foster and Shorrocks 1988b).

3 Poverty in Switzerland

The methodology described in this paper has been applied to the data obtained from the consumption survey conducted by the Swiss Federal Statistical Office for the year 1990 at two different levels. In the first form of the survey, households were asked to report, on an annual basis, general information on their expenditures, complemented with data about their incomes, housing conditions, and such characteristics as their occupation, and the age and gender of each household member. In the second form of the survey, much more detailed information was required from other households regarding their expenditures, but only for a given month. Just the first form of the survey is used in this analysis, as the data cover the same period for each household and are thus more comparable. After having checked for coherence of the data, a sample of 1963 observations remained.

To assess living conditions using the fuzzy index of poverty, first the indicators of deprivation need to be selected. According to the consumption survey data, there are four categories of indicators: housing conditions, the possession of durable goods, equivalent disposable income and equivalent expenditure.[6] The indicators associated with each category are presented in table 1.

The form of the membership function for each indicator now needs to be specified. It can be readily seen from table 1 that there are only two categories of indicators. The indicators labelled 1.1 and 2.1–2.8 are of the dichotomic type, while the remaining ones are continuous variables. For the dichotomic indicators, the membership function necessarily takes the form given by equation 5. For the continuous variables, there are several

6 Income and expenditure were made comparable across households of different sizes and compositions by using equivalence scales. The scales used were the econometric scales estimated by Gerfin, Leu and Schwendener (1994) with a Barten specification.

possible forms of membership functions. However, the choice is confined to the form presented in equation 9 and different values of $\xi_{\min}$ and $\xi_{\max}$ are set to take account of the characteristics of each indicator.

Table 1 **Indicators of deprivation**

1	**Housing conditions**
1.1	Hot water
1.2	Square metres of housing space per person
2	**Possession of durable goods**
2.1	Cooker
2.2	Refrigerator
2.3	Deep-freeze
2.4	Dishwasher
2.5	Washing machine
2.6	Colour television
2.7	Video recorder
2.8	Car
3	**Equivalent income**
3.1	Disposable income
4	**Equivalent expenditure**
4.1	Food
4.2	Clothing & footwear
4.3	Leisure, culture and hotels

Indicator 1.2 refers to the habitable area of the apartment. A habitable area of 25 square metres is taken as the limit below which an apartment may be regarded as too small for a single person.[7] Accordingly, a person living in an apartment whose surface does not exceed that value is supposed to face extreme deprivation. On the other hand, an individual residing in an apartment larger than the average size (50 square metres) is considered not deprived at all.

The second continuous indicator of deprivation found in table 1 is given by equivalent disposable income. The lower limit $\xi^{\min}$ is set at half the value of a common poverty line — defined as half the median of the

7 This limit is in accordance with the current standards in canton Geneva for the payment of housing subsidies.

distribution — and the upper limit ξ^{max} at twice the median equivalent disposable income.[8] By doing so, individuals with less than SFr9308 (Swiss francs) a year are judged to belong entirely to the fuzzy subset of deprived people, while those with more than SFr74 464 a year may be considered to be completely out of poverty[9].

Finally, for the last three continuous variables, related to equivalent expenditure, it was simply decided to define ξ^{min} and ξ^{max} as the minimum and maximum values encountered in the distribution. As a result, the most deprived household, according to its food expenses, spent only SFr342 (A$316) in 1990 and at the other extreme the level of expenditure for food reached SFr17 085 (A$15 777) for the only household totally outside of the fuzzy subset of deprived people. When clothing and footwear expenditures are considered, the minimum value is zero and the maximum value is SFr18 008 (A$16 630). Finally, the minimum level of expenses for leisure, culture and hotels is SFr401 (A$370) and the maximum is SFr76 019 ($A70 200).

The results are presented in table 2. It is notable that the range of $\bar{\mu}$ is very wide. The minimum value is 0.0006, if the lack of hot water in the apartment is taken as an indicator of deprivation. On the other hand, the average degree of belonging to poverty reaches 0.9010 when expenditure

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8 The values taken by the two poverty lines might seem particularly low or high for some of the continuous variables. The justification for these choices is that it is very likely that below ξ^{min} individuals face bad enough living conditions to be considered completely poor and that beyond ξ^{max} they do not belong at all to the set of the poor. In spite of that, the values chosen for ξ^{min} and ξ^{max} for each continuous indicator of deprivation are completely arbitrary. Therefore a sensitivity analysis would be advisable, in order to investigate how the change of those limits would affect the results.

9 For information the equivalent amount is given in Australian dollars. The first limit would be of A$8596 and the second limit of A$68 764. The values in Australian dollars were obtained by simply averaging the daily exchange rate and applying it to the amounts in francs. On no account does it take into consideration the purchasing power parity.

on leisure, culture and hotels is used as an indicator of deprivation. But these results need to be interpreted carefully, especially when comparing values of $\overline{\mu}$ for different types of variables. Although it is clear that $\overline{\mu}$ represents a proportion for dichotomic variables, it is not necessarily true for continuous indicators.

The results concerning the fuzzy proportion of poor households are now analysed according to indicators related to the possession of durable goods. It is apparent from table 2 that the cooker and the refrigerator are two very widespread goods, since only 2.5 per cent of Swiss households do not have them at their disposal. This result is not surprising, because these durable goods are used to store and transform food, which is a necessity. The average degree of deprivation is also low when washing machines are considered. According to the consumption survey, 7.1 per cent of households do not own this good. In this case, too, the presence

Table 2 **Fuzzy poverty in Switzerland**

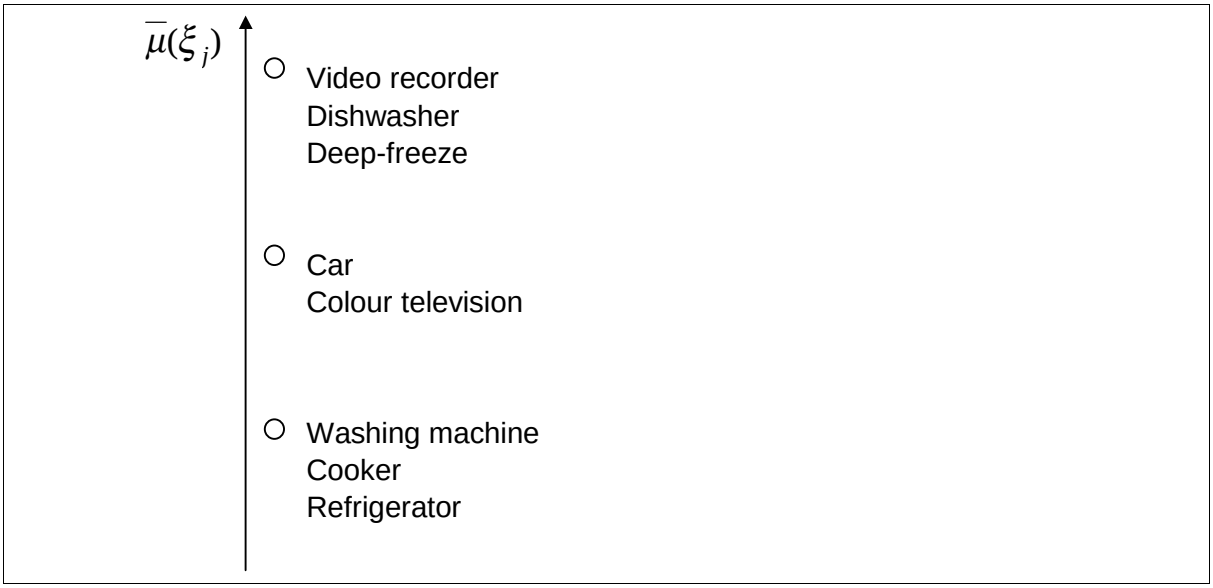
		Indicator of deprivation	Fuzzy proportion of poor households	Weights
j		ξ_j	$\overline{\mu}(\xi_j)$	ω_j
	1.	**Housing conditions**	**0.0445**	**0.3356**
1	1.1	Hot water	0.0006	0.2994
2	1.2	Per person square metres	0.4076	0.0362
	2.	**Possession of durable goods**	**0.1287**	**0.6140**
3	2.1	Cooker	0.0258	0.1475
4	2.2	Refrigerator	0.0252	0.1484
5	2.3	Deep-freeze	0.4119	0.0358
6	2.4	Dishwasher	0.5924	0.0211
7	2.5	Washing machine	0.0714	0.1064
8	2.6	Colour television	0.1551	0.0752
9	2.7	Video recorder	0.6360	0.0182
10	2.8	Car	0.2181	0.0614
11	**3.**	**Equivalent income**	**0.5481**	**0.0242**
	4.	**Equivalent expenditure**	**0.7564**	**0.0262**
12	4.1	Food	0.6778	0.0157
13	4.2	Clothing and footwear	0.8557	0.0063
14	4.3	Leisure, culture and hotels	0.9010	0.0042
		Fuzzy index of poverty	**0.1270**	

of such a durable good among most of the households is not surprising, because it is related to maintaining clothing, which can also be regarded as a necessity.

The results found for the other items belonging to the second group of indicators give more information on the lifestyle of households and on their living conditions. It appears that almost 16 per cent of households do not possess a colour television and 22 per cent do not have a car. Presumably, the possession of the remaining durable goods is more a question of taste. Nevertheless, owning one of those additional items probably gives the households better living conditions. More than half of Swiss households do not have a dishwasher nor a video recorder at their disposal, while only 59 per cent have a deep-freeze. The intensity of deprivation can be summarised according to indicators for the possession of selected durable goods, by ranking them on a scale, as shown in figure 1, where higher values of $\overline{\mu}$ denote a higher average deprivation.

Now the indicators of deprivation related to equivalent expenditures of households are considered. The interpretation of the fuzzy proportion of poor households is not as straightforward as in the case of the possession

Figure 1 **Intensity of deprivation, by durable good**



of durable goods. Here, $\bar{\mu}$ should be considered as the average position of households in relation to two extreme situations — that of the most deprived and that of the most well-off. Keeping this interpretation in mind, it is noted that the equivalent expenditures are on average closer to the bottom end of the distribution[10]. The intensity of deprivation according to different categories of expenditures can be illustrated by figure 2.

Figure 2 **Intensity of deprivation, by category of expenditures**

As would be expected, the average deprivation is the lowest for food expenditure and the highest when living conditions are assessed by referring to expenditure on leisure, culture and hotels. In fact, often the dispersion is less for expenditure on goods that can be considered necessities.

As can be seen from the last column of table 2, which gives the weights associated with the different indicators of deprivation, those related to the possession of durable goods have the highest weight (61.4 per cent), followed directly by those related to housing conditions (33.6 per cent). On the other hand, the monetary indicators of deprivation, concerning equivalent income as well as expenditure, account for only 5 per cent in the aggregation process. This is due mainly to the definition of the membership functions, which tend to give higher privation scores for this kind of variable. Of course, this may be regarded as a weakness of the weighting method as described in equation 16 and could lead to

10 This result is not surprising because of the typical asymmetrical and right skewed form of the distribution, combined with the fact that extreme observations are replaced with values closer to the centre of the distribution.

questioning of the relevance of aggregating indicators of different kinds. As already mentioned, the specification of the weights is crucial. In fact as can be seen from table 2, the values of $\overline{\mu}$ vary a lot between the different indicators of deprivation. For this reason, and depending on the relative importance given to each one of them, the results obtained could vary. Moreover, because of the way the weights are made dependent on the average level of deprivation, the definition of the membership function has a tremendous impact on their determination, especially when dealing with continuous variables. Therefore a sensitivity analysis should be performed on both the form of the membership function and the weighting system in order to check the robustness of the results.

Anyway, these remarks should be a guide to interpreting the overall fuzzy index of poverty FIP from a relative standpoint, when comparing living conditions through time or over different population subgroups. Thus the value of 0.1270 in the last row of table 2 does not have any particular meaning in the absolute. In other words, it would be very difficult to say whether this value reflects good or bad living conditions. The above assertion leads naturally to some decomposition of the global fuzzy index by selected subgroups of population.

4 Decompositions of poverty

This chapter presents two decompositions of the fuzzy index of poverty. For the first decomposition, the population is divided into five subgroups by employment status of the household's head[11]. For the second, five groups are distinguished according to the age of the head. The overall level of poverty for each subgroup considered has been calculated by using the same set of weights during the process of aggregation of the

11 The head of the household is defined in the consumption survey as the person who financially contributes the most to the total income of the household.

indicators of deprivation. By doing so, the fuzzy index of poverty for the whole population is obtained as a weighted average of the observed poverty in each subgroup, the weights being given by the shares of the population. Of course, the weights could be calculated separately within each subgroup, in order to take account of their peculiarities and of the relative importance of each indicator of deprivation. As a matter of fact, some groups of the population might have different needs and tastes and accordingly not give the same importance to the selected indicators. However, preference was given to using the same system of weights for each subgroup, not only because this makes it easier to compare the level of deprivation between the groups but also because there was not enough information for selecting a different set of weights in each case, unless the specification proposed in equation 16 was used.

4.1 Poverty by employment status

For the first decomposition of the fuzzy index of poverty, there are five subgroups of the population, each related to a different employment status. In the first subgroup are households whose heads are self-employed. This subgroup essentially includes traders, entrepreneurs and persons practising a liberal profession. The self-employed represent 6.8 per cent of the whole population. Farmers are not part of this category and form the second subgroup. Their share in the total population is only 4.7 per cent. In the third subgroup are households whose heads are employees. This category is rather wide and heterogeneous, as it contains directors or state employees, junior and senior executives, workers, trainees and apprentices. This subgroup accounts for a large proportion, 64.1 per cent, of the population. The second highest proportion, 21.9 per cent, is accounted for by the fourth subgroup, made up of pensioners. The last subgroup comprises households whose heads practise any other activity and includes unemployed people and students. This subgroup is the smallest one, representing only 2.6 per cent of the whole population.

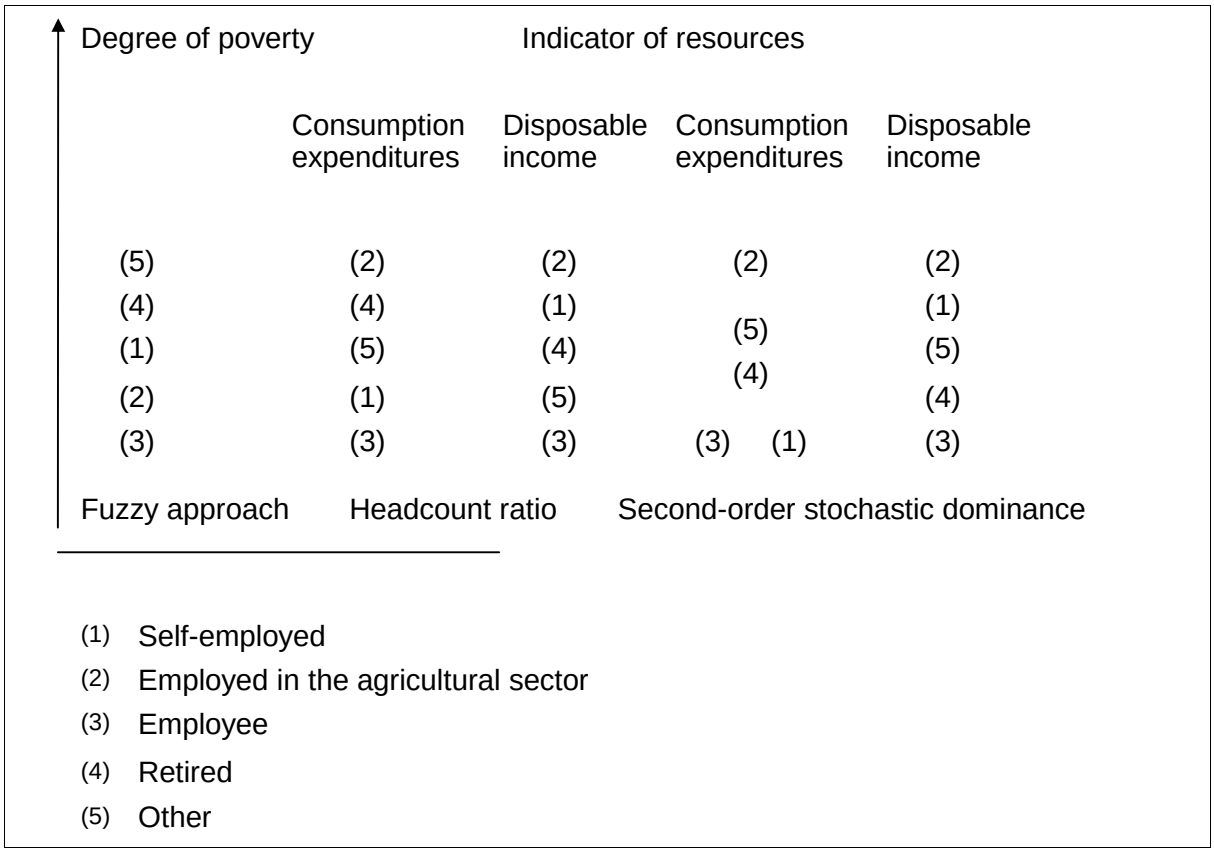
When analysing the results presented in table 3, it is apparent that employees enjoy the best living conditions, according to the fuzzy index of poverty. They are followed by farmers and the self-employed. For those three subgroups, the level of poverty is less than the Swiss national average of 0.1270 and FIP takes the value of 0.1186, 0.1201 and 0.1255 respectively. The households whose heads are retired seem to be more deprived, as their average deprivation reaches 0.1474. The last subgroup presents the highest degree of membership to the fuzzy subset of the poor, with an average value of 0.1811.

Table 3 **Decomposition of fuzzy poverty, by employment status**

	Self-employed	Employed in the agricultural sector	Employee	Retired	Other	Total	
% of pop.	0.0684	0.0465	0.6409	0.2185	0.0256	1.0000	
Indicator	Fuzzy proportion of poor households						Weights
ξ_j	$\overline{\mu}(\xi_j)$	$\overline{\mu}(\xi_j)$	$\overline{\mu}(\xi_j)$	$\overline{\mu}(\xi_j)$	$\overline{\mu}(\xi_j)$	$\overline{\mu}(\xi_j)$	ω_j
1.	**0.0477**	**0.0410**	**0.0512**	**0.0233**	**0.0542**	**0.0445**	**0.3356**
1.1	0.0000	0.0000	0.0009	0.0000	0.0000	0.0006	0.2994
1.2	0.4420	0.3805	0.4675	0.2158	0.5025	0.4076	0.0362
2.	**0.1225**	**0.1091**	**0.1150**	**0.1666**	**0.2013**	**0.1287**	**0.6140**
2.1	0.0447	0.0127	0.0191	0.0386	0.0578	0.0258	0.1475
2.2	0.0655	0.0085	0.0196	0.0323	0.0289	0.0252	0.1484
2.3	0.3994	0.1098	0.4172	0.4650	0.4102	0.4119	0.0358
2.4	0.3338	0.5556	0.5758	0.7202	0.6748	0.5924	0.0211
2.5	0.0684	0.0078	0.0687	0.0766	0.2170	0.0714	0.1064
2.6	0.1783	0.3473	0.1484	0.1113	0.2838	0.1551	0.0752
2.7	0.5297	0.8412	0.5658	0.8157	0.7706	0.6360	0.0182
2.8	0.1177	0.0962	0.1467	0.4657	0.3807	0.2181	0.0614
3.	**0.6426**	**0.8958**	**0.4600**	**0.6779**	**0.7607**	**0.5481**	**0.0242**
4.	**0.7164**	**0.6728**	**0.7507**	**0.7984**	**0.7976**	**0.7564**	**0.0262**
4.1	0.6285	0.5013	0.6789	0.7223	0.7232	0.6778	0.0157
4.2	0.8201	0.9050	0.8381	0.9035	0.8959	0.8557	0.0063
4.3	0.8896	0.9658	0.8881	0.9254	0.9284	0.9010	0.0042
FIP	**0.1255**	**0.1201**	**0.1186**	**0.1474**	**0.1811**	**0.1270**	

It is extremely interesting to compare these results with the ones obtained using other approaches to measuring poverty. In previous work the headcount ratio with a poverty line set at half the median of the distribution[12] (see Miceli 1997, pp. 100–66) and the second-order stochastic dominance technique (see Miceli, pp. 207–26) were used, employing both disposable income and consumption expenditure as indicators of resources. As would be expected, the ranking of the five subgroups differed slightly, depending on which indicator was chosen. Figure 3 illustrates the various situations.

Figure 3 **Intensity of deprivation, by employment status**



Source: Miceli (1997).

12 This definition of the poverty line corresponds to a level of disposable income amounting to SFr18 616 (A$17 191). If consumption expenditure is used as the indicator of resources, the poverty line takes the value of SFr17 503 (A$16 163), according to the above-mentioned definition.

The main difference when a unique indicator of deprivation for measuring poverty is used is the change in the relative position of the self-employed. While they seem to be rather deprived according to their disposable income level, they figure among the most well-off when their consumption expenditure is examined. This is probably due to the way self-employed households report their income — tending to under-estimate it. But when indicators other than just those related to the monetary situation of households are included, it becomes apparent that the living conditions of farmers are also not as bad as a one-dimensional analysis would suggest. Furthermore, retired households, but above all unemployed people or students, display a worsening of their situation when more material conditions are included. The image provided by a multidimensional analysis is surely closer to the common idea of poverty and of its intensity in the different groups of households, according to their employment status.

The results presented in table 3 are now analysed in more detail. If each group of indicators is considered separately, the ranking of households by their employment status is not the same as for the overall fuzzy index FIP. The only thing in common to all the groups of indicators when living conditions are assessed is that unemployed people or students always appear among the households with the highest deprivation levels and the self-employed are always relatively well off.

It is apparent that retired households enjoy the best housing conditions from the point of view of habitable surface area. This can be explained in part by the fact that they often live in older apartments, which tend to be more spacious. Also, they stay in the same apartment most of the time, even when the children leave.

When living conditions are evaluated by considering the possession of some durable goods, it is noted that on average farmers experience the lowest deprivation level. They often are better equipped than other sorts

of households, especially with durable goods directly related to basic needs such as food and clothing. In fact, the rates of deprivation observed for the possession of a cooker, a refrigerator, a deep-freeze and a washing machine are markedly lower than the national average. This is probably because most farmers are isolated from urban centres, forcing them to possess these items. Moreover, less than 10 per cent of the households employed in the agricultural sector do not own a car. Again this represents the lowest deprivation rate. A plausible explanation is that distances to cover are longer and public transport is less developed in rural than in urban areas. On the other hand, there are fewer durable goods related to leisure, such as a colour television or a video recorder, among farmers than other types of households.

The main characteristic of the living conditions of the self-employed is a moderate deprivation in almost all the durable goods except the cooker and the refrigerator. They even rank first regarding the possession of a dishwasher or a video recorder.

The retired tend to possess the various durable goods to a lesser extent than the rest of the population, which is quite understandable when the ownership of a car is considered, for example. On the other hand, this group has the highest percentage of households with a colour television at their disposal. The situation of the 'other' subgroup with regard to durables could be described as moderate on the whole.

When disposable income is used to assess living conditions, the ranking of households remains almost unchanged from the one obtained with the group of indicators related to the possession of durable goods, except for the relative position of the farmers. Their apparent privation is highest in terms of disposable income.[13]

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13 It needs to be pointed out that the ranking obtained using disposable income in the fuzzy approach differs from the one shown in figure 3, derived from the headcount ratio and from the second-order stochastic dominance technique. This is due to the particular form of the membership function.

Finally, when the living conditions of households are estimated using their expenditure on selected goods and services, more or less the same image is obtained as the one depicted by the absence of durable goods as an indicator of deprivation. Thus, retired and unemployed people, as well as students, face the worst living conditions.[14] However, the differences in the level of deprivation for the different groups of population are very small compared with the ones observed when using other groups of indicators. It could then be worth checking whether the differences are statistically significant.

4.2 Poverty by age of head

For the second decomposition of the fuzzy index of poverty, the households are distinguished by age of the head, using five age groups (table 4).

Table 4 **Households by age group**

Age group	Proportion of household
	%
20–29 years	13.6
30–39 years	25.7
40–49 years	20.1
50–64 years	22.6
65 years and over	18.0

The fuzzy proportions of poor households, according to the various indicators or groups of indicators, are presented in table 5.

The results concerning the overall fuzzy index of poverty  are analysed first. From the last row of table 5, two groups of households can be identified. The first group presents a level of deprivation below the national average and is made up of households whose heads belong to the intermediate age groups. The second group of households, which

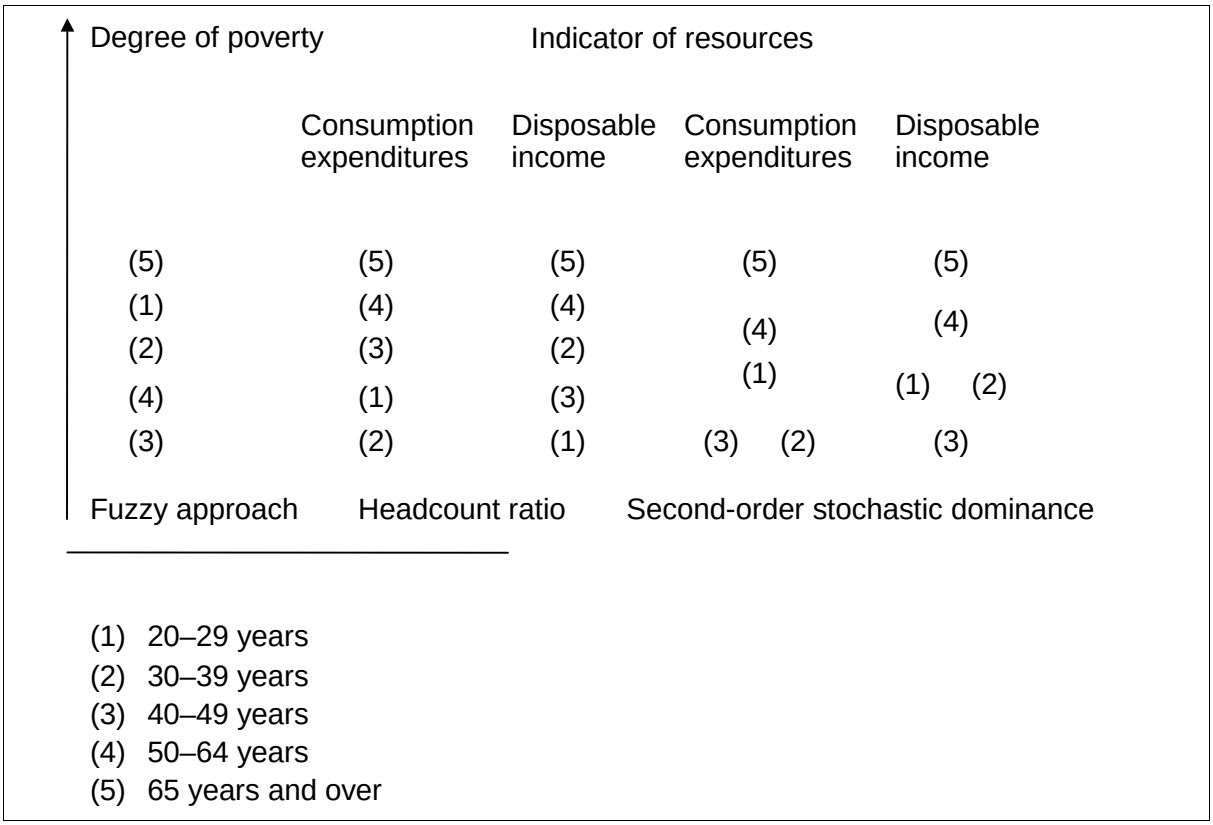
14 The same remark as in footnote 13 applies here.

have young (20–29 years) or old (65 years or more) heads, shows worse living conditions than do most households. If the fuzzy index of poverty is presented graphically on the vertical axis and age on the horizontal axis, a typical U-shaped curve is obtained. This seems to indicate that deprivation is at its highest level at both ends of the adult life cycle. Between these extremes, the level of deprivation goes down, reaching a minimum value for households with heads 40–49 years old, before rising again. The same type of result is obtained if the headcount ratio or the second-order stochastic dominance is used to assess poverty in the various subgroups, although the U-shape is not as marked as in the fuzzy approach. Results from the different approaches are compared in figure 4.

Table 5 **Decomposition of fuzzy poverty, by age of head**

	20–29 yrs	30–39 yrs	40–49 yrs	50–64 yrs	65+ yrs	Total	
% of pop.	0.1359	0.2569	0.2013	0.2262	0.1796	1.0000	
Ind.	Fuzzy proportion of poor households						Weights
ξ_j	$\bar{\mu}(\xi_j)$	$\bar{\mu}(\xi_j)$	$\bar{\mu}(\xi_j)$	$\bar{\mu}(\xi_j)$	$\bar{\mu}(\xi_j)$	$\bar{\mu}(\xi_j)$	ω_j
1.	**0.0535**	**0.0603**	**0.0550**	**0.0272**	**0.0250**	**0.0445**	**0.3356**
1.1	0.0000	0.0023	0.0000	0.0000	0.0000	0.0006	0.2994
1.2	0.4960	0.5400	0.5097	0.2527	0.2322	0.4076	0.0362
2.	**0.1557**	**0.1152**	**0.0925**	**0.1273**	**0.1700**	**0.1287**	**0.6140**
2.1	0.0271	0.0186	0.0119	0.0333	0.0413	0.0258	0.1475
2.2	0.0187	0.0252	0.0098	0.0362	0.0336	0.0252	0.1484
2.3	0.6327	0.3751	0.3263	0.3428	0.4807	0.4119	0.0358
2.4	0.7205	0.5116	0.4699	0.6043	0.7332	0.5924	0.0211
2.5	0.1022	0.0659	0.0430	0.0765	0.0812	0.0714	0.1064
2.6	0.2534	0.1716	0.1418	0.1204	0.1156	0.1551	0.0752
2.7	0.5612	0.5704	0.5597	0.6747	0.8231	0.6360	0.0182
2.8	0.1762	0.1579	0.1071	0.2180	0.4602	0.2181	0.0614
3.	**0.5208**	**0.5268**	**0.4709**	**0.5482**	**0.6855**	**0.5481**	**0.0242**
4.	**0.7964**	**0.7532**	**0.7158**	**0.7337**	**0.8045**	**0.7564**	**0.0262**
4.1	0.7486	0.6765	0.6250	0.6410	0.7314	0.6778	0.0157
4.2	0.8538	0.8477	0.8294	0.8517	0.9033	0.8557	0.0063
4.3	0.8888	0.8981	0.8850	0.9034	0.9294	0.9010	0.0042
	0.1470	**0.1234**	**0.1054**	**0.1198**	**0.1504**	**0.1270**	

Figure 4 **Intensity of deprivation, by age of head**



Source: Miceli (1997).

It can also be seen from figure 4 that the ranking of the groups differs from that obtained with the headcount ratio and the ordinal approach. In fact, when a single monetary indicator is used for evaluating poverty, the worsening of living conditions is roughly an increasing function of the age of the head.

When the groups of indicators are considered separately, the typical U-shape is not found when considering the degree of deprivation in relation to the age of head. In addition, as can be seen from table 5, the different groups of indicators — housing conditions, possession of durable goods, equivalent disposable income and equivalent consumption expenditure — do not provide the same ranking of the subgroups as the one given by the overall fuzzy index of poverty. However, except for housing conditions, the households with a head aged 40–49 always figure among the most well-off and those with a head aged 65 years and over show the highest deprivation.

Focusing first on deprivation according to housing conditions, the results for households with heads aged 65 years and over (subgroup 5) are consistent with the ones obtained for the retired from the decomposition of overall fuzzy poverty by employment status, especially when usable housing area is used as an indicator of deprivation. In fact, the best living conditions are enjoyed by those households whose heads are 50 years of age or more. Nevertheless, the simple observation of housing conditions tends to give an opposite image of deprivation compared with the one obtained with the overall index.

When living conditions are analysed using the possession of durable goods as the indicator of deprivation, the most outstanding fact is that households with heads aged 40–49 show the lowest rates of deprivation, except in the case of colour television. On the other hand, households with heads in the oldest age group nearly always figure among the most deprived.

Turning now to deprivation levels as depicted by disposable income, households tend to be more and more deprived as the ages of the heads increase. The only exception is for households whose heads are aged 40–49, who enjoy the best living conditions from the point of view of disposable income.

Finally, the ranking of households obtained when expenditure is used as the indicator of deprivation is almost the same as the one provided by the use of durable goods. This means that the two extreme age groups (20–29 years and 65 years and over) face the worst living conditions.

5 Summary and concluding remarks

This paper presents an example of the application of the multi-dimensional measurement of poverty using fuzzy sets. The empirical

results obtained for Switzerland in 1990 show that the use of several indicators not only helps in giving a more complete picture of living conditions, but also gives an image of poverty that is closer to what is perceived by just observing reality.

When comparing poverty between groups of the population defined according to the employment status of the head of the household, it was found that the highest degrees of deprivation are among the retired, the unemployed and students. The fuzzy index of poverty appears to be a superior measure to the headcount ratio and even to a second-order stochastic dominance analysis. In fact, although farmers in general have a low level of disposable income and of consumption expenditure, that does not mean that they face worse living conditions than the rest of the population. Actually the fuzzy index of poverty shows that when housing conditions and the possession of durable goods are taken into account, farmers are doing rather well.

The results obtained from the decomposition of overall poverty by age of the head indicate that households with young (20–29 year old) or aged (at least 65 year old) heads present the highest levels of deprivation. Again the results obtained from the fuzzy approach seem more reliable than the ones provided by the headcount ratio or the ordinal analysis, where the group of households with heads less than 30 years old are richer than most of the other groups.

The analysis of poverty presented in this paper is essentially based on an external observer's point of view of what deprivation represents. Not possessing a certain good or of having less than other groups of the population is supposed to increase the sense of deprivation. However, the subgroups identified as belonging to the most deprived might not think they do. The analysis presented here would certainly be improved if indicators reflecting how the households evaluate their own situations

could be included. As an example, households with a retired head may not feel it necessary to possess a video recorder.

Obviously, the results depend strongly on the choice of indicators for this kind of analysis so it would be worth defining an appropriate set of indicators to include in the data, covering all the relevant areas for an analysis of living conditions.

From the theoretical and conceptual point of view, different methods of aggregation and weighting systems could be investigated. Given that both issues are subject to controversy, the evaluation of living conditions using the fuzzy index of poverty should go along with a sensitivity analysis on the form of the membership function for continuous variables as well as a sensitivity analysis on the system of weighting.

Furthermore, the results obtained are subject to sample variability. It would then be interesting to take account of these possible variations in the technique, to see whether the levels of deprivation are statistically different from one another. This would be very useful, especially when dealing with small samples.

In conclusion, despite all the imperfections of the method described in this paper, and all the possible improvements, it can be strongly concluded that this kind of multidimensional approach for measuring poverty is much more realistic than the traditional ones based on a single indicator of resources. Although the interpretation of the final index is not very easy, because it combines indicators of a different nature, it can still give an insight into the major areas of living conditions by separately considering groups of indicators, such as housing conditions, the possession of durable goods and working conditions. The overall fuzzy index of poverty is also shown to be particularly illuminating when comparing several groups of the population.

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