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Open Essays and Researches

Representative Samples, Random Sampling

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Abstract. In the social sciences literature the expressions 'random sample' and 'representative sample' are often used improperly and sometimes even interchangeably by students who seem to think that sample is representative in so far, and because, it is random. In this essay I shall discuss the proper use of 'random', 'representative' and related terms, and I shall argue that no logic nexus exists between the two concepts, nor does any causal relationship between the two sets of phenomena. The analysis begins with the term that raises the most annoying problems, and accordingly is less explored in the literature, viz, 'representativeness'.

Keywords: sampling, random, representative.

INTRODUCTION

In the last quarter of the last century, sample surveys were received as a novelty by the Italian culture, and they rapidly overcame the implicit hostility from the idealist and the Marxist traditions. Quite often, results of surveys on almost any topic would be reported on the front page of newspapers and TV newscasts. In recent years, this survey-mania is fading away, with one remarkable exception: political, and in particular electoral, surveys. Meanwhile, face-to-face interviews have been completely abandoned – at least in large-scale surveys – in favour of less expensive and quicker telephone interviews[1]. Several devotees of methodological accuracy objected that the basic condition for inference from a sample to a population was far from guaranteed through the telephone.[2]

However, «declining research budgets coupled with the need for social science data to inform decision making have led some agencies to encourage the use of internet surveys» (Vaske 2011: 149). «Self-administered sur-

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[1] On telephone surveys, see e.g. Groves (1990); Frey (1995); Creswell (1998); Link *et al.* (2007); Peytchev *et al.* (2011), Häder *et al.* (*eds*., 2012).
[2] See e. g. Cotter *et al.* (1982); Goyder (1987); Körmendi and Noordhoek (1989); Sapignoli (2006); Díaz De Rada (2010).

veys–especially those conducted on the internet–have enabled researchers to collect data easily and cheaply. This boon for scholars, however, comes at a cost» (Berinsky, Margolis and Sances 2014: 752). «Booming informatics have diverted attention from methodological problems» (Marbach 1996: 49).

The flaws associated with internet surveys are numberless: the population is a priori reduced to those who are familiar with computers and spend a considerable part of their time on them; there are no means of having any reliable estimate of its size, but we may be sure that older and busy people, as well as rural dwellers, are practically excluded; there is wide space for self-selection into the sample by those who happen to advocate a particular idea on some topic submitted by the questionnaire; open-ended questions are rarely or never seen; if incentives are provided, quite a few will be induced to check the first answer listed in order to save time; no human being can clarify the meaning of a question or a closed answer. Etcetera.[3]

A few years ago, three political scientists from M.I.T., lamenting that "respondents do not read questions carefully", advocated the introduction of questions in the form of «screeners (who lead) subjects to follow a precise set of instructions when choosing a response option» (Berinsky *et al.* 2014: 739). However – even assuming that such technicalities do improve respondents' attention – this is just a minor instance among the flaws we have listed above.

Before the end of the previous century, a renowned specialist ventured the prophecy that «self-administered surveys, which leave interviewers out of the data collection process entirely, will become the dominant method of surveying early in the 21st century» (Dillman 1998, 2). Less than two decades later, the majority of contributors to a special issue of "Public Opinion Quarterly" (vol. LXXXI, S1, 2017) tended to stress the negative consequences of that de-humanization, viz. the declining response rates, and the advent of competition from alternative data sources. As is normal in such gatherings of opinions from different quarters, points of view were multifarious rather than overlapping. I have been surprised to discover that no contributor was considering an epistemological, rather than simply technical, question.

In about one century, modes of data collection have rapidly shifted: doorstep interviews, mailed questionnaires, calls to landline and (later) cellular telephones, invitations to web surveys, and survey interviews by text. What never changed is the tendency of polling agencies – as well as the academics who resort to their services – to claim that their samples are "random" and "representative".

Half a century ago, in their review of the use of the latter term in scientific literature, Kruskal and Mosteller (1979 b: 111ss) listed the six different meanings they had found more often. They opened their list with «unjustified acclaim… the investigator gives the data a pat on the back by using a seemingly scientific term to raise its stature» (*ibi*: 111). In a previous review, dedicated to non-scientific literature, they opened with the remark that «the term… is sometimes used as a seal of approval… it appears to mean that the sample is well suited for the author's purposes and conclusions… the concept of representativeness is used primarily as an assertive talisman, or as a means of sounding more scientific» (1979 a: 14, 16). In a third review, dedicated specifically to the statistical literature, they find that it «contains its share of vague laudatory use of the expression representative sample», concluding that it is being «misused in both scientific and general publications, mainly in a way suggesting false precision or pseudoscientific glamour» (1979 c: 246).[4]

Yet, before the end of the century, one could find that the most widely spread of the meanings mentioned by Kruskal and Mosteller ('a mirror or miniature of the population') was sometimes distinguished from terms such as 'random', 'randomness' – correctly referred to a procedural characteristic.[5] By now, all the occurrences sound like a lip service paid to a ritual, in the absence of any sign of awareness of the proper meaning of the two terms. Moreo-

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[3] "Those individuals in the United States who have access to the internet have higher educational levels, higher incomes, are younger, live in predominantly urban areas and in predominantly dual-parent families and are of white or Asian/Pacific descent" (US Department of Commerce 2000). Also see Harlow (2010); McInroy (2016); Prasad Nayak and Narayan (2019); Andrade (2020).

[4] Similar judgments had already been pronounced by Kish (1957: 26); Frederick and Mc Carthy (1958 : 32); Campbell and Stanley (1963: 19). According to Eiser, generalizing to a general population of the results from a sample is "an act of faith" (1880/83: 21).

[5] See for instance Seater (1969: 122); Freund and Williams (1976: 93); Marquis (1977); Gilbert *et al.* (1977: 218); Statera (1982, 124); Memoli and Saporiti (1985: 203); Kish (1987: 22); Saris (1989); Bruschi (1990: 337); Cicchitelli *et al.* (1992: 20); Keeter (1995).

ver, the expressions ‘random sample’ and ‘representative sample’ are often used interchangeably by authors who placidly assume that a sample is representative in so far, and because, it is random (or vice versa).

In this essay I shall discuss the proper use of ‘random’, ‘representative’ and related terms, and I shall argue that no logical nexus exists between the two concepts, nor does any causal relationship between the two sets of phenomena. My analysis begins with the term that raises the most annoying problems, and accordingly has seldom – with the praiseworthy exception of the works by Kruskal and Mosteller quoted above – been explored even in the older literature, viz., ‘representative(ness)’.

1. WHAT DOES ‘REPRESENTATIVE’ MEAN?

1.1. The meaning listed with less criticism by Kruskal and Mosteller is that a representative sample must reproduce on a smaller scale the characteristics of the population: “a subset of a population that seeks to accurately reflect the characteristics of the larger group” (1979c: 252).

In order to assess if and to what extent A accurately reflects certain characteristics of B, one must be able to compare A and B as regards these characteristics. As a consequence, in order to establish whether or not a sample represents certain characteristics of the population, it is necessary to know what these characteristics are in both the sample and the population. A thin minority of authors seem to take this obvious requirement into account, by reporting a table with the results of some sample-population comparison, and even less[6] take the trouble to remind the need for such a comparison to the readers.

First consequence: Since the population (or at least some of its characteristics) must be known, we cannot state that our sample is representative of an indefinite, purely hypothetical universe.[7] Nor can we say anything about representativeness unless we have – through a census or a similar large-scale gathering – the needed information about the population. Which entails that nothing can be stated about all the properties that are never considered by censuses[8] – i. e. all the psychical properties to say the least.

Second consequence: since the sample must be known as well, we cannot speak of representativeness until the sample has been drawn. Whereas randomness is a property of a (selection) procedure, representativeness is a property of its outcome. It is assessed by comparing some of the population’s characteristics with the corresponding characteristics of the sample. This comparison takes into NO account the selection procedure by which that particular sample was generated. It makes no sense to speak of a random outcome, nor does it make any sense to speak of a representative selection procedure.[9]

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[6] Besides Kruskal and Mosteller (1979c: 253), Kendall and Buckland (1960: 249), Suits (1963: 55), Tufte (1977: 311), Cartocci e Raggi (1979: 79), Cicchitelli *et al.* (1992: 20).

[7] In my opinion, the only scientists who can legitimately speak of ‘universe’ are the astronomers. However, this is one of the most frequent terns in statisticians’ language, where it designates any collection of persons or objects or event from which a sample is drawn (see e. g. Kotz *et al.,* 2004). This meaning is improper because the universe is endless by definition, while no population can have numberless members. As it happens, the improper use of a term is no accident: it is required in order to legitimate the resort to formulas that permit the inference of a (monovariate) figure (such as a mean) from a random to a population. That terminological artefact conceals the fact that such formulas are conceived assuming numberless populations, or endless drawings of samples, while in the social sciences only one sample is drawn at a time, and the populations rarely exceed thousand individuals. Similar remarks can be found in Kish (1957: 7) and De Finetti (1985: 216).

[8] This conclusion is correctly drawn by Pinto and Grawitz (1964: 701). But since a distribution in a sample *can* be confronted with the corresponding distribution if that is supplied by an appropriate census, universal statements such as «representativeness cannot be empirically checked» (Perrone 1977: 76. Also see Henry 1997: 102; Hedges 1997: 338) are unwarranted.

[9] Very few authors stress the crucial fact that «Randomness is a property not of an individual sample but of the process of sampling... The tern ‘sample’, strictly interpreted, need not imply anything about the manner in which the observations are selected» (Wallis and Roberts 1956: 114 and 314). «Randomness relates to the mode of selection, not to the resultant sample» (Moser and Kalton (1958/1979: 84).

1.2. What are those characteristics of the population that we want to reproduce on a smaller scale? In traditional logico-philosophical parlance, they would seem to correspond to properties (or attributes). In the jargon of empirical social sciences, they would be called 'variables'.

And what does "reproduce on a smaller scale" mean? Answering this question involves unpleasant consequences (which probably explains why it is hardly ever asked). The unpleasant, albeit inevitable, answer is reached through the following chain of arguments.

What must be reproduced on a smaller scale is the distribution of states on a property, or – in sociological jargon – of values on a variable. If that property were a constant, it would be enough to assess the state (value) it takes in any individual (case) whatsoever in order to know what states (values) it takes in all cases in the population. This is exactly what a physicist does when he resorts to any convenient specimen of a compound in order to measure its spectrum, electrical conductivity, or other properties: he is certain that his findings will hold true for all other possible specimen of the same compound. Therefore, unless we take it for granted that the property we are studying can take at last two different states in two population's cases, the entire sampling process is meaningless.

Whenever a property's possible states (are at least) two, the distribution of states among the cases becomes important. The property will have a certain distribution (say, D) in the population and another distribution (say, d) in the sample. When we compare a sample and a population, we are in fact comparing the D distribution and the d distribution for one or more properties.

This stated, the meaning of the expression "reproduce on a smaller scale" gets a little clearer. Strictly speaking, "to reproduce" would mean to proceed in such a way that, for each property considered, the d distribution is the same as the D distribution. But this is impossible in that, by the definition, the sample contains fewer cases than the population. By adding the expression "on a smaller scale", we take that circumstance into account: since it cannot be the same as D, the d distribution should be isomorphic to it for each of the properties investigated.

But what does 'isomorphic' mean? The two Greek roots of the term are *isos* (= equal, equivalent) and *morfé* (= form). This suggests that the graphic representations of the two distributions must be equivalent. If we represent the frequencies of the various states with two histograms (one for the population, one for the sample) and substitute the percentages for the frequencies, the two histograms should perfectly overlap: the percentages of cases in the corresponding categories of both distributions should be the same.

One could object that, thus stated, the requirement of perfect isomorphism of the two distributions is too strict. I have no difficulty in acknowledging this, as I am aware that such requirements would be satisfied in ideal cases only. However, one of the functions of ideal types is to provide a standard to which actual situations may be referred to in order to call attention to the presence and size of the differences (Weber 1904).

What size differences are we willing to tolerate in practice? How many percentage points? For which and how many categories? In the case of properties that we consider continuous, what kind of discrepancies are we willing to tolerate between the two curves portraying the distribution of states in the sample and in the population? Shall we compare the areas beneath the two curves in correspondence with various pairs of points on the X-axis? Or shall we just compare means and standard deviations? Or shall we be satisfied with comparing medians and quartiles?

We have never read or heard of any proposal of a criterion to be adopted in order to confer – for either discrete properties or continuous ones –the official seal of representativeness. No threshold has ever been established below which that seal should be questioned or rejected.

One may object that it is ridiculous to insist on such a precise cut-off point and call 'representative' whatever falls on one side of the boundary and 'non-representative' everything that falls on the other side. I wholeheartedly

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[A] selection procedure aimed at achieving a representative outcome may be conceived and designed only if it regards *one single property*, or at most two or three properties. See below, § 4.

concede this point, but cannot avoid remarking that a major part of classical statistics, i. e., "hypothesis testing", is entirely based on precisely such blunt cut-off points.[10]

However, if we cannot separate 'representative' and 'non-representative' by a sharp cut, we should acknowledge it and think of representativeness as a property that can assume an endless number of intermediate states between presence and absence. On the contrary, the term has always been used in dichotomous form; in science, as in everyday life, a concept of degree is often simplified into a dichotomy when we prefer not to bother about it. Moreover, the border between the two alternatives in this particular dichotomy has been left fuzzy to say the least. No limit having been set, everyone uses the term as he pleases, and many samples are dubbed "representative" regardless of the differences in distributions of any variables between them and the corresponding population – granted that advance information on the latter be available, which is rarely the case – or just by fiat, without bothering to document any degree of correspondence between sample and population on any variables.

1.3. There is more to be said on the point. Eighteenth- and nineteenth-century error theory, nineteenth-century pre-inferential statistics and twentieth- century inferential statistics, all share an essentially monovariate approach.[11] They are based on the examination of distributions of but one property at a time or of more properties only if they are independent from one another. On the other hand, practically all empirical research in sociology, political science and social psychology is multivariate under two aspects:

a. The research design is multivariate, i.e., it provides for the gathering of information on many properties at a time. In the context of sample surveys, for example, it would be pure folly to set a complex organizational machine into motion just to collect information on only one or two properties – and in fact this never happens, despite the lip service paid to Popper's orthodoxy, which calls for empirical testing of isolated hypotheses (see criticism in Rodolfi 2001);
b. Not only is the entire design multivariate, but so are most of the models behind every single application of statistical techniques. These models, within the limits imposed on their articulation by technical difficulties, attempt to reproduce the complex network of interrelationships between properties that can be observed in reality.

The fact that sampling occurs in the context of a multivariate research design has some obvious consequences on the possible meanings of the term 'representative'. As we mentioned above, two distributions can be compared only if we have information on both of them. Therefore, if the information we possess concerning the population comes from a census, the comparison can be performed only for properties which have been assessed by the census (in fact, such comparisons regularly involve the same few basic properties; i. e. the interviewee's age and sex, and the location of the city where the interviewee lives). However, the really crucial point is that any correspondence between the distributions of one or more properties in a sample and in the population does not legitimate inferring an analogous correspondence between the distributions of other properties. Even assuming it has been ascertained, representativeness does not carry over from one property to the next.

In 1929, the two Italian statisticians Gini and Galvani showed, through analyzing data from the 1921 Italian census, that a "purposive" selection of a sample so that it be representative on a few properties (as suggested by the Norwegian statistician Anders Kiaer as early as 1895) implies no guarantee at all about representativeness with

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[10] The absurdity of such crudely dichotomous criteria has been pointed out, among others, by Hogben (1957: 30); Selvin (1957); Rozeboom (1960); Morrison and Henkel (1970: 36 and 138-140); Tufte (1970: 439); Tukey and Wilk (1970: 338); Deutscher (1973: 202-203); Henkel (1976: 34-36 and 83-84); Carver (1978); Cohen (1994). The criticism has grown sharp in recent decades (see Kline 2004; Novella 2015; Amrhein and Greenland 2017; Denworth 2019). Yet the blunt cut-off point is still regularly used by most biologists and psychologists, and by a good deal of physical and social scientists.

[11] «Statistical sampling theory... suffers from the decisive deficiency of being monovariate... [Howewer,] in the stage of analysis every sample-base survey is multivariate» (Harder 1969: 153). Also see criticism by Carver (1978), Quinn and Dunham (1983), Johnson *(*1999*)* Stephens *et al.* (2005).

regard to other properties not considered in the selection procedure.[12] As is to be expected, the less one property correlates with the properties considered in the selection process, the greater the discrepancy between the first property's sample and its population distributions turns out to be. Therefore, if we have made sure that the sample is representative in relation to property X, within the limits mentioned above, we can reasonably expect it be sufficiently representative in relation to other properties highly correlated with X. We cannot say anything, however, concerning all other properties. In particular, one simply is not entitled to infer any degree of representativeness in relation to psychological traits, opinions, and values on the basis of substantiated representativeness with regard to a few socio-graphic properties.

The foregoing remarks lead one to perceive what has been called the *paradox of sampling:* «In order to know that our sample is representative, we must know what the characteristics of the population are, so that we can judge whether the sample reflects them properly; but in that case, we have no need of the sample at all» (Kaplan 1964: 239-40).[13] When we do not possess the corresponding information about the population, then we can say nothing about representativeness on any property.

So, by analyzing the concept of representativeness from the standpoint of the multivariate nature of social science research designs, we meet with a paradox. Furthermore, if one takes the multivariate nature of most models of relationships between variables into account as well, one fully perceives the dramatic inadequacy of that concept with respect to the wonderful power with which it is usually credited in social science.

Capecchi pointed out the consequences of models' multivariate nature on statisticians' ritual claim to establish the optimal size of a sample for inference to the population through a monovariate formula: «The size of a sample cannot be determined on the basis of a single variable... In addition – and this is really decisive– when sociological research is undertaken, one obviously intends to cross-tabulate two or more variables; at this point the estimation of n should take into account the range of variability not of each single variable considered alone, but of the bi- or multi-dimensional variables which ensue» (1972, 51). For this reason, before speaking of representativeness, one should take into account the joint distributions of all variables included in each model.

a. If none of the variables in the model are treated as cardinal, one should compare pairs of multi-way cross-tabulations – one from the population, one from the sample. In order for the sample to be representative of the population with respect to the specific model being tested, the percentage of cases in each of the cells formed by the logical product of the states of the variables involved should be approximately the same in both sample and population (see § 1.2). Since – within the bounds implied by marginal frequencies – cell frequencies may be distributed in a variety of ways, even if the distributions of two or more variables, separately considered, do attest to a sample-population isomorphism, there is no guarantee that their joint distributions be isomorphic as well.
b. If one or more variables in the model are treated as cardinal, besides the condition mentioned under point a, it is also necessary that within each cell of the non-cardinal variables the (separate *and* joint) distributions of the cardinal variable in the sample and the population be isomorphic.
c. If all the variables in the model are considered cardinal, not only must each variable's distributions in both sample and population be isomorphic; so must the joint distributions of all the model's variables, simultaneously considered.

As was mentioned earlier, these requirements are undoubtedly too strict, but it is equally absurd to establish, with a minimum degree of precision and inter-subject acceptabi1ity, exactly how much slack should be tolerated in each cell of the joint distributions.

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[12] Gini and Galvani's (1929) finding was, and still is, very frequently quoted in the relevant literature. Already in the following decades it was taken for granted that representativeness – whatever it might mean – do not transfer automatically from one variable to another. See Stephan and McCarthy (1958: 31-32); Stuart (1968: 613); Castellano and Herzel (1971: 16); Nowak (1971/77: 296); Chiari and Corbetta 1973: 653); Kruskal and Mosteller (1980: 184-9).

[13] Among those who called the readers' attention on that paradox, Castellano and Herzel (1971: 8); Ballatori (1988: 75); Marradi (1997: 49); Trobia (2008: 785).

1.4. The chain of arguments developed so far should have clarified the reasons why expressions such as 'representative sample', 'sample representativeness' and the like are considered far too vague and general, and therefore improper. This does not imply that the adjective 'representative' and related nouns should be banned altogether, as it has been advocated by Kruskal and Mosteller (1979a: 24); Duncan (1984: 603) and Marbach (1996: 64)[14]. It does imply that their use should be limited to statements having a potential, tangible empirical counterpart. A sentence such as "Our sample is representative of the population as regards age" is acceptable in so far it is backed by a diagram or a table comparing the sample's and the population's age distributions.

Of course, this guarded use of the term undermines its evocative impact. It is one thing to tell a client or a reader "my sample is representative", implying "therefore, with but a few thousand dollars, you now know what million consumers/individuals would buy tour product" or "therefore, the theories corroborated or suggested by these findings are the scientific truth". It is quite another thing to say: "Our sample distribution as regards sex diverges from the national distribution, as certified by the last census, by 2,2%; the sample distribution as regards level of education diverges by 5,7%; and we can say nothing at all about all the other properties on which our survey did collect data because they have never been included into a census."

The second kind of statement simply is not likely to arouse a reader's enthusiasm, nor to loosen potential clients' purse strings. Indeed, it makes them wary and suspicious and provides them with at least a vague idea of the extremely narrow epistemological confines within which social science operates, and of the consequent questionability of all its claims. We must make up our minds whether science is most germane to uncritical confidence and loosened purse strings, or to awareness of its own limits. This is precisely the unpleasant consequence it was hoped to exorcise by avoiding analysis of the meanings of the term 'representative'. Such analysis, in fact, could only lay bare the ideological (in the sense of positivist ideology) nature of the way the term has been employed in the past, and will certainly continue to be used, by scholars and polling institutes.

The distortions undergone by expressions such as 'random sample' and 'random sampling', which enjoy a much more solid foundation in probability theory, are relatively less serious.

2. WHAT DOES 'RANDOMNESS' MEAN?

2.1. Statistics and methodology handbooks state that, if the members of a sample are drawn by a table of random numbers, every element of the population has the same probability of being chosen. Over and above this minimum requirement, «simple random sampling… requires a clear definition of the population to be sampled, a complete list of all its elements, and the assumption that all such elements are statistically independent of each other» (Lazerwitz 1968: 279).[15] This is true not only for every member, but also for every combination having the same number of members.[16] The second condition is by no means warranted by another form of random sampling, called "systematic" in order to distinguish it from the simpler form. However, if a population's members are listed in the proper way, the systematic form offers important advantages[17] that will be dealt with in §4.

On the other hand, simple random sampling offer the advantage that its basic tenet can be easily shown to the layman through the image of an urn from which some balls are drawn. I believe that recourse to such an immediate and familiar image has done much to discourage unwarranted expansion of the meaning of the term 'random'. By that image, the requirement that all members of the sampled population, just like all the balls in the urn, should have exactly the same chance of being chosen has been made crystal clear.

[14] Kish (1957: 26) remarks that the expression "representative sampling' is becoming "easier to avoid because it is disappearing from the technical vocabulary". A cursory review of the most recent literature would hardly support his forecast.

[15] Less detailed definitions in Yule and Kendall (1937: 371); Cochran, Mosteller, and Tukey (1954: 16); Wonnacott and Wonnacott (1969/1972: 19); Nowak (1971/1977: 298); Castellano and Herzel (1971: 263); Smelser (1976: 211); Statera (1982: 125); Orsi (1985: 198-9); Lohr (1999:18); Thompson (2006: 1225); Taherdoost (2016: 19).

[16] See Hansen *et al.* (1953, I: 9); Cochran, Mosteller e Tukey (1954: 22); (Kish 1957: 39); Corbetta (1972: 350); Chiari and Corbetta (1973: 484); Mitra and Pathak (1984: 1536); Thompson (2006: 1227).

[17] See Aitken (1939); Cochran (1946: 168-70); Yates (1948); Kalton (2014); Arnab (2017, §4).

By underscoring that actual differences from the ideal-typical, balls-in-an-urn situation, the layman can be easily and effectively led to understand that when somebody haphazardly interviews people on the street, he is not engaging in random sampling: there is no defined population the members of which all have the same chance of running into the interviewer and attracting his attention. In fact, even if it were possible to define a population of humans who "happen upon that particular place", some of them would happen along more often during the interviewer's working hours; some would more easily attract his attention, etc. The ideal-typical image of the urn is helpful in that it makes one familiar with the idea that an equal probability for everybody to be included in the sample is a *necessary and sufficient* condition for randomness. As a first approximation, this permits a perfectly satisfactory, albeit simple, definition of the expression 'random sample'.

2.2. At a deeper level, however, this admirable simplicity is spoiled by the problems we usually face in social research. By stating that an equal probability of being selected for all members of the population is *not* a necessary condition of randomness, "stratified disproportionate" sampling -– widely used in many disciplines – is provided with a solid foundation (see Neyman 1934; Lazerwitz 1968; Lohr 1999, §3; Hunt e Tyrrell 2001; Kalton 2014). For practical and theoretical purposes, it is possible to divide the population into k subsets of known size and to draw from each of these (since each member of the population must have a non-zero probability of being selected) at least one sample unit. Thus we will have a sample divided into k subsamples, each drawn from one of the population's k subsets. Afterwards, equal probability can be reinstated by weighting each subsample's data with a coefficient inversely proportional to its corresponding "sample fraction" (the ratio between the subsample's size and the related popu1ation subset's size).

The idea of diversified weighting illustrates particularly well the ontological atomist assumptions which lie at the heart of statistical inference theory, as well as the ontological mechanistic assumptions implied by the entire research orientation (principles and ensuing techniques) based on the data matrix (Marradi 2007, §§ 4.3 & 5.3. Also see Cipolla 1988: 207; Marradi 1989:69, Wand 1992, §3; Di Franco 2015).

A mechanistic – as distinguished from an organistic – ontology is shown in statistical inference in so far as a variable's values (which represent, with varying degrees of faithfulness, a property's states) are separated from the elements to which they belong and projected onto several other unidentified elements. These procedures assume that any state is totally independent of the element to which it belongs, i.e., need not be considered in the light of the elements' states on other properties. This is defensible if the element is a mineral or a mechanical robot; it is not so plausible if the element is an organism; and it is even less plausible if it has a psychological and cultural unity as well.

An atomistic ontology is shown by the fact that individuals are thought of as fully interchangeable, just like the atoms of a chemical element, since any one of them can stand for an indefinitely high number of the others (the same remark in Hogben 1957: 49; Medawar 1957; Pinto and Grawitz 1964: 623; Campbell 1986). If adopted in its entirety, this ontology would make sampling useless, as it would be enough to do research on but one individual in order to automatically extend whatever is discovered to all individuals, just like a chemist has no doubts that any nitrogen atom will behave exactly like the nitrogen atoms he's currently studying. However, statistical inference theory stands short of self-destruction because it steers clear of integrally adopting an atomist ontology; rather it resorts to it – as Weber said of dialectic materialism – much like a taxicab to get into or out of according to convenience.

Not surprisingly, this self-contradictory/ambivalent attribute reveals just another paradox: stratified sampling, a procedure devised in biology in order to facilitate statistical inference to populations of organisms, can be defended only by resorting to ontological assumptions which deny organisms their specificity and consider them exactly like any given non-organized group of chemical elements.

By admitting that even just one individual (and here lies the crux of the matter) can represent an infinite number of other individuals, the concept of representativeness is transferred from a relationship between distributions (in which case atomist ontology can remain behind the scenes) to a relationship between individuals considered in their entirety (here atomist ontology need come to the fore). In other words, whereas the idea is tenable – with the exception of the above-mentioned charge of mechanist ontology – that a distribution of states on one property can represent, thanks to their isomorphism, another involving a larger number of cases, it is absolutely unacceptable to let an individual (with all his states on innumerable properties) represent another one. Unless – I repeat – one adopts an atomist ontology, which –however – voids inductive statistical theory of any use and meaning, in that it makes the presence of distributions impossible (if all elements are the same, then their states on any given property are also the same: if all states are the same, there is no distribution).

From this standpoint, inferential statistics is self-contradictory. Statistics itself depends on the presence of distributions: if all the elements of a population had the same state on a (any) property, there would be no need for statistics. Nevertheless, it flirts with an atomist ontology whenever it has to justify a sample-to-popu1ation inference; it calls upon it more explicitly in the case of "disproportionate stratified" sampling – or any form of weighted sampling[18].

2.3. In social science surveys, sampling procedures are not an end in themselves but are instrumental in the following interviews. If an individual included in the sample is not found by the interviewer, if he refuses to be interviewed or if he does not return a self-administered questionnaire schedule, it is as if his name had never been drawn: he simply drops out of the sample. As per common experience, the drop-out rate reaches as far as 70 to 80% of an initial mail survey sample, and as 30 to 50% of a personal interview sample – and is steadily increasing (De Leeuw and De Heer 2002; Burkell 2003; Rose, Sidle, and Griffith 2007; Stoop 2005; Curtin, Presser, and Singer 2005; Stoop 2012). "A common occurrence in data gathering, non response, can result in a sample which is technically a non-probability sample... It makes no sense to make statistical inferences from non-probability samples to the existing populations " (Henkel 1976: 25 and 80). "Un campione probabilistico in partenza può non esserlo più in arrivo, al momento dello spoglio dei dati, per un elevato numero di non-risposte" (Chiari and Corbetta 1973: 649). "An incompletely achieved probability sample ceases to be a probability sample, although it usually continues to be called one" (Stuart 1968: 615).[19]

The further trouble is that, in general, non-respondents tends to differ from respondents as regards lifestyles, economic situations, education levels, age and other properties crucial for the social sciences. In other words – as many methodologists[20] have remarked– the subset comprising individuals randomly drawn from a sample frame who elude contact (or refuse to be interviewed or fail to return a postal questionnaire) is *not* a random sample of all individuals drawn from the sample frame: individuals who belong to certain categories have a higher-than-average a priori probability of ending up in such a subset. The replacement of non-interviewable subjects with other subjects – a widespread practice[21] – also introduces biases of unknown size and effects with respect to the original randomly drawn sample, and therefore it undermines the claim of having interviewed a random sample (Chiari and Corbetta 1973: 646; De Cristofaro 1998: 51).

Instead of interviewing substitute sample units, efforts should be directed at attempting to contact and interview a random subsample of non-respondents in order to estimate the magnitude of differences, and thus have at

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[18] The same contradiction lies at the heart of all nomothetic positions in the social sciences, i.e., of all attempts at estab1ishing empirical propositions of universal scope about objects (individuals) which admittedly cannot be substituted one for another.

[19] Also see Perry (1979: 314), Grosset (1994), Jones (1996: 55), Koch and Blohm (2016), Banerjee and Chaudhury (2010). The common practice of applying to any kind of sample the formulas which assume a strictly random sample is blamed – besides Stuart – by less authors than one could expect: Kish (1953: 188-9 and 1957: 576); Corbetta (1972: 351); Henkel (1976: 24); Fowler (1992: 39); Falk and Greenbaum (1995); Hubbard (1997).

[20] See e. g. Mosteller (1968: 120); Henkel (1976: 25 and 76-80); Armstrong and Overton (1977); Perry (1979: 314) Barton *et al.* (1980); Kriz (1988: 93); Groves *et al.* (*eds.,* 2001); Ullman and Newcomb (2006); Groves and Peytcheva (2008); Shih and Fan (2008); Nishinoure (2015). In mail surveys, it is more likely that older people with a medium-high cultural level will return the questionnaires, whereas it is less likely for people with a full-time job outside their homes or scarcely-educated people. Self-employed people or people with a liberal profession reply only if they are interested in the specific problem covered by the survey. If the questionnaire is administered by an interviewer, he/she will find it difficult to contact people who work outside their homes, will encounter refusals caused by indifference or mistrust in the central areas of cities and in neighborhoods inhabited by marginal groups, etc.

[21] See e.g. Kish and Hess (1959); Rubin (1987); Vehovar (1999); Rubin and Zanutto (2002); Siddique and Belin (2008); Baldissera *et al.* (2014).

least an idea of the bias introduced by the contacting and interviewing procedures, compared to the initial randomly drawn sample. But there is no guarantee that such a subsample, comprising subjects who were finally interviewed after additional efforts, will in turn be a random sample of all subjects who for some reason were not interviewed the first time around. Indeed, it is reasonable to think that this subsample possesses characteristics which are in some way intermediate in nature with respect to those of individuals interviewed the first time around and those of individuals who continue to elude interviewers or reject the interview (see e.g. Voogt and Saris 2005; Densconbe 2006; Sydow 2006; Vives *et al*.).

2.4. Unlike the concept of representativeness, which presents the theoretical difficulties illustrated in § 1, the concept of random selection is extremely simple, at least in theory, and –– thanks to the balls-in-an-urn image – clear even for an average user. This simplicity is however illusory when the concept's range is extended and the corresponding procedures are applied to situations bearing no resemblance to the ideal-typical situation.

Human beings differ from balls in an urn under two crucial aspects: apart from situations of captivity,[22] they are not at the researcher's disposal – unlike the balls, which are at the complete disposal of anybody who sticks his hand into the urn – and they are totally free not to answer the researcher's questions even should one find them – whereas balls cannot refuse to be drawn.

In other words, a researcher can draw a random sample of balls from an urn as long as he wants to, just as he can draw a random sample of names from a list, as long as he wants to. However, in the latter case, random sampling of names is a necessary but insufficient condition for obtaining a random sample of people: if a researcher wishes to know the opinions and/or other non-public characteristics of the people whose names were drawn, it is necessary that all those individuals be contacted and cooperate – which is highly improbable unless they are, in some way, forced to do so.

Despite this fact, almost always it has been taken for granted that the concept of random selection can be non-problematically applied to survey research involving human populations. This is just another of a long series of cases in which conceptual instruments and procedures developed in other disciplines have been integrally adopted by the social sciences without adapting them or reducing the accompanying cognitive claims on the basis of the peculiarities of social science objects (several critical essays on that account can be found in Marradi, cur., 2017).

3. RANDOMNESS OF THE SELECTION PROCEDURE AND REPRESENTATIVENESS OF ITS OUTCOME

3.1. Let us now examine the relationship between the two concepts of randomness and representativeness. As anticipated in the introduction, many authors give for granted that the randomness of the selection procedure entails the representativeness of its outcome, or makes it highly likely. «For any conclusions to be reliable, the sample selected must be representative of the population, *e. g. a random sample*» (Smith 1969, II: 353; italics ours).[23] Unfortunately, this assumption is obviously false: it is not difficult to show, in fact, that there exists no form of logical implication between randomness of the selection procedure and representativeness of its outcome. The former is not at all a necessary condition of the latter, much less a sufficient condition. «Among the random samples that we can draw from a population, some may be extremely far for being representative on any property» (Castellano and Herzel 1971: 11; also see Kish 1995: 819). «Unless enough is known about a population to make sampling unnecessary, one cannot guarantee that any sampling method, random or other, will produce a 'represen-

[22] In the technical literature, by the term 'captivity' a situation is meant in which the subject is, even temporarily, and for reason whatsoever, at the researcher's disposal.

[23] Also see Johnson and Jackson (1959: 44); Fisz (1963: 504); Perrone (1977: 76-77); Memoli and Saporiti (1985: 212); De Vaus (1986: 53); Scheaffer *et al.* (1987); Ballatori (1988: 75); Bruschi (1996: 207); Vergati (1994: 37); Sandrini (1998: 86); Posa and De Jaco (2005: 6); Vaillant (2005, § 1.7); Porras Velázquez (2017).

tative sample'» (Wallis and Roberts 1956: 338). "A miniature is constructed purposefully rather than through a process of probability sampling" (Kruskal and Mosteller 1979b: 120)

3.2. Even the most careful and effective simple random sampling will not guarantee that the resulting sample will be representative with respect to any given variable or combination of variables,[24] much less that it will be representative *tout court* – an expression which has been criticized in § 1.4.

Unlike what has been discussed in § 2, this fact does not depend on our sampling human populations: no representativeness (on any property) is ever guaranteed when a sample is randomly drawn from any type of population. Let us suppose our ideal-typical urn contains 100 white balls and 100 black ones, and we draw one ball at a time, record its color, put it back into the urn, shake the urn and draw again. In this case each drawing is an event which is totally independent of the previous one: the probability of drawing a black ball is the same (1/2) no matter what the outcome of the previous drawing and of all the previous drawings (Wallis 1942: 230; Pfeiffer 1978; Siegmund 1921, § 11).

If we draw a sample of two balls, there is a probability of ¼ they will be both black, ¼ they will be both white, and ½ that one will be black and one white, i. e., representative with respect to the property 'colour'. That probability rapidly decreases as the size of the sample of balls drawn from the urn grows: it is already less than one-third (20/64) with a six-ball sample, less than one-fourth (924/4096) with a 12-ball sample, about one-seventh with a 16-ball sample, about one-ninth with a 50-ball sample, and so on.[25]

A simple causal relationship between randomness and representativeness is even less tenable if one takes into account all the complications listed in § 1 – the properties of interest are more than one, and not necessarily dichotomous; interest lies in the relationships between properties and therefore in their joint distributions; and so on. Yet, even a hyper-simplified situation like the ideal-typical one described above is enough to show that random selection procedures do not suffice for generating representativeness, i.e. are not a sufficient condition.

Once again, currently held views lead to a paradox; if random selection procedures produce representative (*tout court*) samples, it follows that, in all possible random samples of the same population, the variables should have the same distribution, the same bi- and multi-variate relationships among themselves, and so on. In other words, such random selection procedures should produce samples which are identical under every possible aspect, and therefore – in practice – samples comprising the same individuals.

However, it is easy to ascertain that any sample randomly drawn from the same population will be different from any other. This sample variability is so well known and so pivotal that classical statistics built upon it the concept of sampling distribution (the distribution of values assumed by any given parameter in different randomly drawn samples from the same population)[26]. It seems obvious that if every random selection should generate representative samples, the concept of sampling distribution would be useless, in that there would be no distribution; given any parameter, its value should be identical in all drawn or draw-able samples of any size.

3.3. Let us now examine more closely the other thesis anticipated in § 3.1, viz., that random sampling is not a necessary condition for representative outcomes. This means that, "representative" samples (within the limits set in §. 1) can be obtained even if the selection procedure is *not* random. Indeed, I will argue in favour of a more demanding thesis; if one wishes to be certain that a sample will be representative on one or more properties, one must consciously resort to non-random sampling techniques.

This thesis is equally valid in the ideal-typical, balls-in-an-urn situation and in situations actually met with in sociological research[27]. Let's start with the former. Suppose we know that an urn contains 100 red balls, 100

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[24] As we will see on § 4, a systematic sample will guarantee representativeness with regard to one, two or at most three variables, if the sampling frame has been built on the basis of those variables.

[25] If we draw a sample of three balls, or any sample containing an odd number of balls, it is not possible, strictly speaking, to obtain a perfectly representative sample with respect to colour, since balls are indivisible.

[26] Hansen and Hurwitz (1943); Yates (1949); Lipson (2003); Levine (2006, § 7); Pandis (2015).

[27] When a quota sampling system is being adopted. See below.

green ones and 100 blue ones, and that we want to draw a sample of 10 balls which is perfectly representative of the urn's contents with respect to colour. If we adopt a random sampling approach, we have about 8,5 chances in 100 of obtaining such a sample. The only way we can be sure of obtaining a colour-representative sample is to look inside the urn while we pick the balls in such a way that colour proportions are respected. But such a selection procedure is anything but random: as soon as a fifth ball of any given colour has been drawn, all the other balls of the same colour will be discarded until we pick the fifth ball of the other colour – which will put an end to the exercise.

Suppose now we have to interview a sample of inhabitants of the city X, about which census publications supply joint distributions for sex and age groups. If we adopt a quota-sampling system and want to faithfully reproduce this distribution in the sample, we have to build a "quota grid" establishing how many males and how many females are to be interviewed within each age group. This general grid is then subdivided into several sub-grids – one for each interviewer taking part in the data gathering.

Whenever an interview is completed, the interviewer adds a unit is in the corresponding cell of her/his grid; if – as usually happens, given the differing degrees of accessibility and willingness to participate of different types of subjects – the various cells in the grids are filled at different rates, each interviewer will concentrate her/his efforts on the interviewees belonging to the quotas most difficult to complete. As soon as the number of interviewees assigned to a given cell of her/his quota grid is reached, the interviewer will stop looking for that type of individuals.

Here, just as when we look into the urn before choosing a ball, we do not trust on chance but rather steer our selection procedure. Random sampling is utterly incompatible with the goal of guaranteeing representativeness on selected variables. This does not mean that randomness and representativeness are incompatible; it just takes us a long way from the assumption that chance automatically generates representative samples. Either we accept to be led by chance, and in this case we are anything but certain about what our sample's characteristics will be; or we want to predetermine a few of these characteristics: in that case we must steer the selection procedure. There is no escaping this alternative.

In fact, this alternative is clearly present in the history of surveys. Up to the fifties, representativeness occupied a privileged position, and most survey samples were obtained through "quota" sampling. The "purposive" sampling criterion (i. e., ensuring representativeness with respect to a few selected variables), proposed by the Norwegian Anders Kiaer in 1895, was not seriously challenged by theoretical statisticians until 1926, when both Arthur Bowley and Adolph Jensen recommended random sampling in their reports to the International Statistical Institute.

The transition process[28] from purposive to random sampling was very slow because statisticians realized what was being lost (the certainty of representativeness with respect to a few selected variables), while they had no clear understanding of what was being gained.

Before looking into random sampling's advantages, it should be said that purposive sampling is methodologically advisable compared to random sampling whenever there are good reasons to concentrate attention on a very low number of properties: e.g., in factorial designs.[29] Quota sampling is the inevitable solution even for a normal survey when a list of the members of the population is unavailable, and it can be defended in other specific situations.

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[28] On that process, see Westergaard (1932); Stephan (1948); Moser (1952); Fienberg (1976); Kruskal and Mosteller (1980); Bellhouse (1988); Fienberg and Tanur (2105).

[29] A factorial design allows the effect of several factors and even interactions between them to be determined with the same number of trials as are necessary to determine any one of the effects by itself was with the same degree of accuracy. It was first used by John B. Lawes and Joseph H. Gilbin in the Rothamsted Experimental Midlands (cfr. Hall 1905) and then perfected by Ronald Aylmer Fisher in the same experimental station (1926). Relevant contributions to that sophisticated technique are due to Box *et al.* (1978), Montgomery (1984), Juju (2014).

4. SYSTEMATIC SAMPLES

A systematic sample[30] can be drawn only if we a complete list of the population's members is available, and members are identified by a sequence of numbers going from 1 to n. If members are listed, as usual, in alphabetical order, there is practically no risk that such an order be associated with a/the variable(s) respect to which we want the sample to be representative of the population.[31] Then we divide the list in as many segments of equal length as is the number of individuals we want to include in the sample: if the members of the population are 200.000 and we want to draw a sample of 200 individuals, we will divide the list in 200 segments of 1.000 members each.

The following step is picking, from a list of random ones, a number between 1 and 1.000 (in the example, the total of members in each segment). Let's suppose it to be 483. The third and last step is automatically inserting into the sample each individual whose identification number ends by the figures 483: i. e., the individuals identified by 483, 1.483, 2.483... and so on, the last being the individuals identified by the number 199.483.

One possible trap in this procedure is the choice of a segment of inappropriate length, as will be clarified by the following example. Let's suppose we want to draw a sample of 50 from an infantry regiment composed by 50 squads of 12 members. The length of our segment will be 12, and we will pick from each squad a number between 1 and 12. Further suppose that, as is common in the army, the first individual listed in each squad is the squad's corporal. If the number drawn will be 1, we will have a sample composed by corporals only; if it will be ≠1, we will have a sample with no corporals.

This is what Lazerwitz calls «the danger of periodicity... If there are any properties associated with the similarly numbered elements that form a sample, the characteristics of such a sample can be drastically affected» (1968: 297). One case of periodicity is the amount of sales in a supermarket, which is higher in the last days of the week: in that case, one should avoid of choosing segments of length 7 – or 6, if Sundays are excluded.

A common distortion of systematic sampling happens in telephone surveys, when each page[32] of the directory is adopted as a segment, and usually the name appearing on top of the page is selected for the sample. Names of firms, offices, or shops are discarded in favour of the next following name of an individual. The "bread-winner bias", consisting in the fact that usually the bread-winner name appears in the directory, can be made up for by adopting – as in any telephone survey – some complex tables (see Kish 1949) in order to decide which member of the family has to be chosen for the sample. More difficult is to make up for the "single bias", consisting in the fact that no member of the family is available as a substitute for the individual whose name appears in the directory.[33]

Of course the two latter types of bias characterize every telephone survey, whatever is the sampling technique they resort to. We would not devote an entire paragraph to that particular form were it not for the possibility it offers to draw a sample which is both random *and* representative of a population *with respect to one*, or at most two[34], relevant properties. These properties cannot be cardinal (interval or ratio, in Stevens' classification), and – for reasons we will see later – the lesser the number of their categories, the better.

How this can happen will be clarified by a example. For the sake of simplicity, but with no loss of generality, we will limit the problem to drawing, from the adult population of a middle sized town, a sample being *both* random and representative as regard gender and residence in a district. Let's suppose our Midtown has a population

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[30] The first to propose that method have been Bowley and Burnett-Hurst (1915). Besides those already mentioned above, see Madow (1949); Chiari and Corbetta (1973: 485); Kruskal and Mosteller (1980: 180); Jachan (1982); Cipolla (1988: 190 ss).

[31] An equivalent result can be obtained "if the population units are thoroughly shuffled or mixed before being ordered on the list" (Kish 1957: 118). Also see Cochran (1953: 208-212).

[32] Or a series of adjoining pages, if a smaller sample is desired.

[33] In the (unlikely) case that the distribution of families by number of members in the area covered by the survey is available, and the relevant question is asked from the person who answers the telephone call, by comparing the two distributions it will be easily shown that singles are overrepresented in the sample. On "bread-winner bias" and "single bias" see Brick *et al.* (1995).

[34] As a matter of fact, by this technique it might be possible to draw a sample representative of a population with respect to more than two properties. The practical and mathematical reasons for avoiding that extension of the technique will be dealt with at the end of this paragraph.

of 400.000 adults, distributed in 8 districts (that will be named A to H). The first step in our procedure will be to dress a list having on top all the adult females living in district A, followed by all the adult males living in district A, then by all the adult females living in district B, all the adult males living in district B, and so on. The list will end with all the adult males living in district H.

Then we will divide our list in n segments of equal length, where the size of n only depends on the number of individuals we want to draw in our sample. If we want a sample of 400 individuals, then the list has to be divided in 400 segments of 1.000 individuals. The third step is drawing a random number between 1 and 1.000. Let's assume it is 604. As a consequence, the sample will include every individual whose identification number ends by the figure 604: i. e., the individuals identified by 604, 1.604... and so on, the last being the subject identified by 399.604.

My task is now to convince the reader that through this procedure we obtain a sample that – besides being obviously random, since any identification figure has the same chance of being extracted at the beginning – is also representative of the population of Midtown as regards gender and residence in a district. Let's start by the latter, and by supposing that 63.834 adult citizens (i. e. 15,96% of the adult population of Midtown) live in district A. If we follow our criterion of inserting in the sample every subject identified by a number ending with the figures 604, we need only a bit of patience to discover that 63 members (i. e. 15,75%) of the sample will be living in district A.[35]

I hope it is self evident that the same mechanism is at work with any other district.

In order to easily obtain a random sample having the property of being representative with respect to gender, we just have to reshuffle putting all the women in the first part and the men in the second one, then follow the procedure described above. However, if we keep the same list alternating women and men within each of the 8 district and we follow the procedure described above, we may aim at obtaining a random sample having the property of being representative of the joint distribution of gender and residence in a district within a given population.

As it is obvious, nothing can be declared as regards representativeness on any other property. In principle, there is no obstacle preventing one to introduce a third variable – for instance, education (higher/ intermediate / lower). Let's see an example where all the characteristics of the previous one (a town with a population of 400.000 adults, distributed in 8 districts; a sample of 400 subjects). In this case, the first step in our procedure will be to dress a list having on top all the adult females with higher education living in district A, followed by all the adult females with intermediate education living in district A, then by all adult the females with lower education living in district A, then all the adult males with higher education living in district A, and so on. The list will end with all the adult males with lower education living in district H. The number of segments who need be identified and ordered is 48, the product of a dichotomy (gender) by a property with (in this case) 3 categories, by a property with (in this case) 8 categories. Besides being rather tedious, this work requires unceasing attention, because any change in the definition or order of segments will inevitably entail the collapse of the entire building.

Moreover, the exponential multiplication of segments entailed by the introduction of third and fourth stratifying variables is unwarranted due to a mathematical reason: the difference of 0,5% between the percentages of a segment in the population and in the sample (which, as we saw, is the maximum difference possible with systematic sampling), while it may be considered negligible when the segments comprise anyway a large number of subjects, may be relevant when at least some percentages are smaller – which is an inevitable consequence of a larger number of segments. Looking at all this panorama, it easily understood that what is important, more than the mere number of properties, is the product of their categories: stratifying by three dichotomies produces much less segments than stratifying by two properties having 8 categories each.

Summing up. Systematic sampling is a necessary and sufficient condition for drawing a sample which is both random and representative of the corresponding population with respect to a small number of (non-cardinal) properties. If the property of interest is only one, the advantages offered by this procedure have no negative counter-

[35] Due to intuitive mathematical reasons, is very unlikely that the two percentages (of the population and of the sample) be exactly the same. For the same type of reason, it is impossible that this difference be higher than 0,5%. Negative differences (lower percentages in the sample than in the population) in district A will necessarily compensated by positive differences in other districts, and at the end of the game the algebraic sum of differences will tend to zero – allowing for minimal rounding errors.

parts. If the properties are two or three, all depends by the logical product of their categories: if this product is large, both practical and mathematical considerations advise against resorting to this type of sampling.

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