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MULTIDIMENSIONAL SCALING IN ECONOMIC RESEARCH

Abstract. A relationship between the theoretical terms and the observational ones, called also a perceptual or observational, is essential for scientific research of empirical type, including social sciences and economic sciences. This relationship cannot be clarified in terms of a complete definition but only by a partial definition. This methodological truth is well known since R. Carnap's works. Later on it was developed in methodology of sciences by the Polish logicians: Przełęcki, Poznański and Kamiński.

Multivariable techniques are necessary when one wants to define the relationships between variables in economic and social sciences. However, the results obtained in such analysis are often unsatisfactory because the residual variance is too large. Multidimensional scaling proposes quite a different methodological approach for seeking the relationship between the theoretical terms and the observational ones.

This paper aims: (1) to show what kind of methodological proposition is multidimensional scaling; (2) to show what are the possible directions of applying multidimensional scaling to social and economic analysis; (3) to define the multidimensional character of decision analysis.

Key words: multidimensional scaling, theory of data decision analysis.

1. METHODOLOGICAL ESSENCE OF MULTIDIMENSIONAL SCALING

Multidimensional scaling is a method of scientific enquiry which is based on inductive inference schema. It is based on assumption that reality which is an object of the enquiry, is of a different level of complexity, i.e. multidimensional. Human being (e.g. researcher, price analyst, expert), when expressing his relation to the reality (cognitively, preferentially, behaviorally), operates using the dimensions (interpreted usually as variables) which enable him a cognitive "possession" of that reality. According to this assumption, one can say that human being is multidimensionally scaling the reality, i.e. he is schematizing and categorizing the reality in accordance with some learned style which is corresponding to the defined methodological, cultural or professional pattern.

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In social life situations, in economic domains, in professional practice and in research activities we are facing a kind of a natural scaling, i.e. intuitively obvious comparing and systematizing the perceived objects, events, situations, concepts or ideas. The object of this scaling is a reality which is existing really, hypothetically, intentionally, or ideally.

Multidimensional scaling techniques propose a reconstruction of a multidimensional space of the investigated reality where the compared objects will be located. It is a systematizing space which contains the analyzed objects. In decision situation it is a preference space; in evaluating situations it is an evaluation space; in economic situations it is a behavioral space; etc. A mode of existence of the systematization space and strictly speaking the defined configuration, i.e. location of the considered objects in this space, depends on two factors: (1) behavior of the subjects, and (2) the logical and mathematical assumptions of the computer program which reconstructs the systematizing space and the configurations of the compared objects in this space.

In order to clarify the assumption and aim of multidimensional scaling, let us give an illustrative example. Let us imagine that a geographer lost a map of a region but he knows the direct distances between the particular cities in this region. In such a situation multidimensional scaling enables us to reconstruct a map of this region.

In a similar way, having the stated "closeness" or similarities between the pairs of different consumption goods, it is possible to reconstruct their location in consumers' space. There are many possible ways of using multidimensional scaling in social and economic sciences, to reconstruct various systematizing spaces for economic behaviors of individuals or companies. Scaling might be also used to systematize various groups of technologies, resources, products, services, industrial waste, behaviors of persons employed in the particular cycles of technological process, taxpayers, behavior of trade union members, of managers, etc. Other examples of applying multidimensional scaling could be research on semantic space of social concepts, preference space of consumers, space of the perceived smells, tastes, trade marks. This methodology can be also used to investigate public opinion, preferences, attitudes and political opinions.

It is worthy to underline also a possibility of using the techniques of multidimensional scaling in the methodology of social and economic sciences, and particularly in systematizing of theories, models, paradigms, research methods, indicators, coefficients and terms. The subjects are here the scientists, experts, analysts and scholars.

Multidimensional scaling might be used to investigate: (1) individual persons, events, situations, processes (e.g. typical or not typical, rare goods), (2) differences between the individuals; (3) differences betweengroups of persons, classes of events, situations or processes; (4) differences between the groups. An example might be scaling of efficiency of the defined economic activities by the individual experts; perceiving of similarities of companies, work positions, professions by the individual advisors, employees, unemployed persons; classification of the concepts or theories by the individual academicians; environmental risk perception in the particular technology or investment by the individual experts or by the inhabitants of local community. In turn, an example of investigation which aims to state the main tendencies in a group might lead to perceiving the multi-dimensional characteristics of one's own company, professional group, regional group, trade group; expressing opinion in economic domain, on technological characteristics, on moral issue – by the defined social group, professional group, trade union people, etc.

What kind of data could be the object of multidimensional scaling? Directly, for multidimensional scaling may be used the data which define similarity relationship (closeness or distance) between the elements of any n-element set, where for n is defined a condition $4 < n < 100$. The condition for n depends on a concrete computer program for scaling.

Similarity is defined as data for scaling and can be measured on an interval scale or on a quotient scale. For example, the data for scaling can be obtained by comparing consumer relation between the consumption goods (e.g. distance between various products of the same category or between the particular kinds of services) or the perceived relation between the potential investors, the future shareholders, the officers from central institutions (e.g. Commission for Valuable Papers and Stocks), closeness between the stock companies. The data should be prepared as a batch file for the computer program for multidimensional scaling in a shape of a data triangle of $n-1$ rows and $n-1$ columns which comes from measuring on an interval closeness scale between the combined in pairs the compared elements of a set.

However, indirectly for multidimensional scaling may be also used the data which come from measuring on independent interval scales or even on ranking scales of the individual elements of the analyzed set. Between these measures may be stated the appropriate correlation coefficients dependent on a type of a measuring scale. Thus, multidimensional scaling may be used for measures of independent objects on internal scale (five-point scale), but also the outcomes of the order scale (e.g. ranking the elements of a set).

The obtained correlations will be interpreted as the measures of connection (e.g. similarity, closeness) and as such may be combined in a shape of a data triangle of $n-1$ rows and $n-1$ columns, they may also be used as a batch file in multidimensional scaling.

2. THEORY OF DATA AS A LOGICAL BASE FOR MULTIDIMENSIONAL SCALING

A theory of data by C. H. Coombs (1964) can be recognized as a logical background for multidimensional scaling. This theory seeks an unifying system which would allow to systematize the data obtained by using various techniques and research methods. From a development of behavioral sciences point of view (where belong, among others, such disciplines like sociology, economics, and psychology) elaboration of a unified and logically coherent system of data classification is of a great theoretical and practical importance, because it shows how to systematize the background of behavior measurement itself.

A starting point for a theory of data is various kinds of recordings which are the outcome of concrete techniques and research methods. Analysis of the formal structure of data enables us to state that a deeper analogical connection could be recognized between some of the data. A base for this connection is a relational intrinsic structure of the data. According to C. H. Coombs, each behavioral data which is a result of empirical research, is not a directly observed behavior but a relational character, as its essence is a relationship between the stimuli and the individuals, or between the stimuli themselves, if it is assumed that the same individuals are reacting to the same stimuli.

C. H. Coombs distinguishes the three phases of scientific enquiry when his theory of data is considered (see Fig. 1).

Phase 1: the scholar is separating the recorded observations from an universum of the potential set of information by applying the designed research and measurement procedures.

Phase 2: the primary observations are systematized into the data by finding relational bonds between appropriate stimuli and the individuals.

Phase 3: reconstruction of the m-dimensional systematizing space in which are located the analyzed elements of the n-element set (the inferred classification of the individual subjects and the stimuli recognized by a computer program).

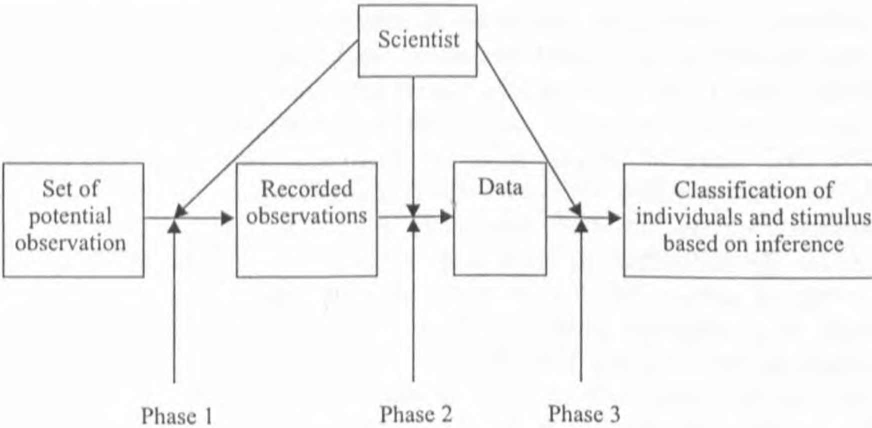

Fig. 1. The phases of construction of data in behavioral sciences (according to Coombs 1964)

Each element of a set (stimulus, object, behavior, event) is presented in multidimensional scaling as a point in m-dimensional space. A number of dimensions of a space depends on the traits and properties of the compared elements of a seta as perceived by the subject. The subject (i.e. observer, analyst, expert, scholar) who is perceiving the stimuli, may also be presented in this space in such a way that the point representing each individual being investigated, means a maximum preference of the stimuli presented. According to such interpretation, the relation constituting individual data is indicated by the distance between the points or a sector of a m-dimensional space.

The most advanced methodologically are the techniques of collecting the preference data (of type: choose r elements form n-element set; or of type: rank n elements according to the defined attribute).

The most fundamental mathematical problem for multidimensional scaling is to find a way of transferring the primary measurement data onto the distances in a space. In order to reach this, the configurations for the points (that is a set of coordinates) should be fixed in multidimensional space, which correspond to the analyzed objects, decisional options, etc. However, this transformation should be done in such a way that the rank order of the input data (batch file) corresponds to the rank order of the distances in multidimensional space which comes from the defined configuration of the points of the space. This fitting should mimimalize a random function called a stress. There are two ways of defining this function: (a) a procedure of monotonic regression of Kruskal, and (b) a procedure of the imagined rank order of Guttman. Both procedures are used in a standard version of a computer output, e.g. in the program MINISSA which is an analytical stage of scaling.

Different types of space are usued in multidimensional scaling, depending on the assumed needs. There are in a usage: the city block matrix, the Euclidean matrix, the Minkowski's matrixes (among which are distinguished so called dominance matrixes or maximize matrixes).

The first stage of scaling is of an analytical character. This stage is based on reconstruction of systematizing space for the analyzed (perceived or valuated) objects, i.e. the elements of a set. There may be systematizing spaces for the individual persons (analysts, experts, decision makers) or for the group of subjects (e.g. consumers of a certain age, social status). An example of a computer program which enables to reconstruct this kind of systematizing space is the MINISSA.

The second stage of multidimensional scaling is a synthesis of the scaling outcomes obtained in the analytical stage. The program PINDIS can be used for this kind of scaling which aims to compare the individual configurations in systematizing space. For example, a company produces n assortments of a commodity for r various markets. Is is important for the strategy of marketing management to state what are the preferences for n assortments in each of the markets, what can be obtained using the MINISSA program (an analytical one), and then one can ask a question how are these spaces mutually related (how they fit the target market which is the most significant for a company). In order to reach this purpose the PINDIS program can be used for which the input data are the individual configurations (i.e. the coordinates of the points) obtained e.g. in the program MINISSA (see: Biela 1992, 1995).

3. MULTIDIMENSIONALITY IN DECISION ANALYSIS

Decision situation may be one of the domains where multidimensional analysis can be applied. Here an explorative possibilities are very extensive. If we define the decision situation as an ordered five:

$$DS \stackrel{df}{=} \langle A, H, \{p(h_j)\}, u_{ij}, I \rangle$$

where:

$A = (a_1, a_2, ..., a_i, ..., a_n)$ – a finite set of possible alternative actions;

$H = (h_1, h_2, ..., h_j, ..., h_n)$ – a finite set of possible states of the world (hypothesis);

$\{p(h_j)\}$ – probability distribution on h_j that depends on alternative actions a_i;

u_{ij} – the Cartesian product $A \times H$, so that $u_{ij} = a_i \times h_j$;

$I = (i_1, i_2, ..., i_t, ..., i_k)$ – the set of actions which enable the subject to obtain new information about the utility of actions or about the probability of the states of the world.

Decision analyst or decision maker perceives many aspects, planes, dimensions in a decision situation, however, not at the same time because of his bounded cognitive capacity. In decision analysis one can find the "transition" moment from one dimension into another one, what explains so called intransitivity of the preferences in many contexts. In accordance to the rationality postulate one can expect that: if a person wants to choose A, than B in a decision situation, and if this person wants to choose B than C. Thus when these options are presented in pairs, the same person wants to choose A rather than C, when A and C are compared in a new pair. Formally, this situation may be formulated as

$$[(A > B) \cap (B > C)] \rightarrow (A > C).$$

This postulate is one of the axioms of the classical utility theory. Unfortunately, behavioral research says that this axiom which seems to be a fundamental for rationality of human behavior, is not fulfilled in people's decision making situations.

What is the reason of intransitivity in human preferences? Isn't it an evident lack of rationality in human behavior? It may be that people are not rational beings. However, it seems that the reason on intransitivity in preferences is not a lack of logic in human thinking or emotional instability in people. A lack of rationality seems to be here only a very surfice phenomenon. A principle of transitivity in preferences would be fulfilled when people would operate a simple, one-dimensional utility scale which is assumed in the axioms of the classical utility theory. In such a case lack of transitivity in preferences would mean a lack of rationality in human behavior in decision situations. However, people are operating with a multidimensional utility scale when considering various alternative options in decision making situations (Huber 1983). Intransitivity of preferences in many situations may be explained by decision maker's "transit" in his analysis into another dimension rather than that with which he was operating whem comparing the previous alternatives. Thus, when considering A with B and B with C, the person considered some other dimension of utility scale than when this person compared A with C.

Operating with multidimensional scale requires not only scaling on the particular dimensions, but also evaluating the importance of these dimensions, i.e. their weighting. A fundamental ontological assumption of multidimensional scaling is that people in cognitive processes, evaluative processes and in decision making are: weighting the dimensions and scaling the objects on the particular dimensions. Integrating of these elementary functions aims to state a configuration of the comparing objects, i.e. their location in a systematization space. Both the two elementary functions (weighting the dimensions and evaluating the objects on the dimensions) and the integration of these functions, aim to cognitive systematization of the considered elements, i.e. company surroundings, segments of a market, consumers' preferences.

Such a systematization is a kind of cognitive "possession" of the analyzed reality. A need for cognitive "possession" of the situation is a motivational base for systematization. Satisfying this need reduces a fear of chaos, randomness in activity and prevents from not choosing the best alternative in a given decision situation. Operating with multidimensional scale in decision making situations was not an object of many methodological analysis. The first were the authors working in decision making analysis (e.g. Huber 1983; Łukasik-Goszczyńska 1974). Assumption about operating with multidimensional scale requires in consequence to accept a hypothetical construct, i.e. a theoretical concept which denotes a systematizing space of cognition of the defined economic environment. Dependently on what is the object of analysis, the systematizing space may deal with a market of products and services, a capital market, or a labor market. Table 1 shows some possibilities of multidimensional scaling which aim to reconstruct various systematizing spaces in market economy environment. The examples indicated in Tab. 1 show various domains of economic reality. These may be the object of multidimensional scaling in decision making situations of a manager who is considering strategic decisions for a company which is functioning in domains of market products and services, capital market or labor market.

Table 1

Examples of spaces in multidimensional scaling for market economy pillars

Pillars of market economy	Content of systematizing space
1. Products and services market	A. Consumer spaces 1. Consumer needs space 2. Declared consumer preferences space 3. Consumer behaviors space 4. Market segments space B. Producers and tenderers space 1. General standing of producers space 2. Participation in market space 3. Profitability of producers functioning in a market

Table 1 (condt.)

Pillars of market economy	Content of systematizing space
2. Capital market	A. investors space 1. Investors segments space 2. Short-term allocations space 3. Long-term allocations space 4. Investors preference space 5. Portfolio allocations space B. Capital market offers space 1. Investment risk of stock companies 2. Stock companies space C. Capital market institutions space D. Spaces systematizing the investors in capital market
3. Labor market	A. Work offers spaces 1. Part time work offers spaces 2. Full time work offers spaces B. Unemployment spaces 1. Actual unemployment spaces 2. Unemployment segments spaces

4. FINAL REMARKS

Multidimensional scaling is undoubtedly a method which may enrich economical analysis, and particularly decision making analysis by contributing new methods dealing with measuring multivariability. Good example are the managerial dimensions in decision making. This example illustrates how rich can be the extension of systematizing spaces within one domain of analysis.

Of course, multidimensional scaling should not be treated as a panacea which can solve all econometric or psychometric problems. For example, this method can not be used to substitute for statistics which are appropriate to test causal connections and to verify research hypothesis.

Multidimensional scaling can undoubtedly be useful in first stages of reasoning, evaluating, analytical procedures or applying – when it is necessary to systematize the collected data and then to formulate a hypothesis, diagnosis, judgements or evaluations. If managerial decision situation is the case, multidimensional scaling can essentially help in shaping and designing decision analysis.

There is also one more attractive way when multidimensional scaling can be used, that is an integrating various opinions and evaluations which deals with one issue. In that case multidimensional scaling , when firstly the program MINISSA (or some other of this kind) and then the PINDIS are used, can be a tool for building methodological consensus in a world of experts, specialists and authorities who represent various approaches, methods, techniques, concepts and schools and behave like people in the Tower of Babel.

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WIELOWYMIAROWE SKALOWANIE W BADANIACH EKONOMICZNYCH

W badaniach naukowych typu empirycznego (do których należą również nauki społeczne i ekonomiczne) istotne znaczenie ma określenie związku pomiędzy terminami teoretycznymi a terminami empirycznymi. Związku tego nie da się ustalić w postaci definicji zupełnych, lecz tylko i wyłącznie przez definicje cząstkowe. Ta prawda znana jest już od czasu prac R. Carnapa, a została utrwalona i rozwinięta w metodologii nauk przez polskich logików: Przełęckiego, Poznańskiego, Kamińskiego. W określaniu związków pomiędzy analizowanymi zmiennymi w naukach społecznych i ekonomicznych konieczne jest stosowanie technik wielozmiennowych. Wyniki uzyskanych analiz nie są jednak zadawalające z uwagi na ich zbyt wielką wariancję resztową. Nieco inne podejście metodologiczne w poszukiwaniu związku między terminami teoretycznymi i empirycznymi proponuje skalowanie wielowymiarowe. Artykuł omawia założenia metodologiczne skalowania wielowymiarowego, teorię danych C. H. Coombsa (1964) jako podstawę logiczną tego skalowania oraz przydatność tej metody w analizie decyzyjnej. Wskazano, iż skalowanie wielowymiarowe może okazać się przydatne w pierwszych etapach pracy badawczej, eksperckiej, analitycznej czy aplikacyjnej, gdy należy usystematyzować zebrane dane i na tej podstawie przystąpić dopiero do formułowania hipotez, sądów, diagnoz, ocen. Istnieje jeszcze jedna możliwość wykorzystania skalowania wielowymiarowego, a jest nią mianowicie integrowanie różnych opinii oraz ekspertyz w przedmiotowej kwestii.