A MULTIDIMENSIONAL COMPARATIVE ASSESSMENT METHODOLOGY FOR POLICY ANALYSIS: A MULTI-COUNTRY STUDY OF THE AGRICULTURAL SECTOR

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Abstract

This paper offers an overview of assessment methods for physical planning, with a particular focus on the agricultural sector. An attempt is made to link multi-criteria analysis to meta-analysis by applying rough set theory as a framework for comparative study. An empirical application on the explanation of productivity differences in OECD countries is used to illustrate the potential of this approach.

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1. The Changing Scene of Policy Analysis

The past decades have witnessed drastic changes in the context and contents of policy analysis. The conventional optimisation paradigm is increasingly being replaced by procedural or accountable modes of planning, in which a great variety of different motives and policy orientations play a role. In addition, long-range uncertainty (technical, social and financial) hampers a straightforward planning perspective (e.g., based on blueprint modes of planning). And finally, the lack of social consensus compels planners to develop new policy analysis tools able to incorporate various types of conflicts among different actors, different regions or localities, or among different policy objectives.

In modern policy preparation and planning there is a need for a proper assessment and evaluation framework in the public sector with the goal to increase the efficiency and effectiveness of government decisions. In this sector in particular, a wide range of decisions is to be made without a clear reliance on the market system. This is partly caused by the nature of choices in the public sector (with emphasis on multi-actor democratic modes of decision-making) and partly by the complexity of government projects (with long-lasting and often uncertain implications). And it is indeed increasingly understood that public decisions based on market forces alone do not necessarily lead to optimal results. Structural market failures as well as unexpected external factors may require an adjusted and efficient policy mechanism that can lay the foundation for an improvement of the actual socio-economic developments within a community or society. Consequently, various methods have emerged in the realm of policy analysis in which an extended market evaluation plays a prominent role. The most well known example of such evaluation methods is based on social **cost-benefit analysis** (as an operational application of welfare theory). This method is the basis of numerous policy assessment methods and has been successfully applied in many case studies. Despite its many merits, it is also recognised in modern policy analysis that this tool has some limitations, because not all relevant welfare implications of policy initiatives can be expressed in the 'measurement rod of money'.

To cope with the weakness of monetary evaluation, a diversity of modern assessment methods has been developed over the last ten years to provide a complement to social cost-benefit analysis and to offer a new perspective for procedural types of decision-making, in which various qualitative aspects are also incorporated. Many of these methods simultaneously investigate the impacts of policy strategies on a multitude of relevant criteria, partly monetary, partly non-monetary (including qualitative facets). They are often coined **multi-criteria methods** and are also known as multi-assessment methods (see e.g. Janssen 1992 and Nijkamp et al. 1992).

Although a great number of assessment studies has been undertaken in the regional, transportation and environmental field, it is worth mentioning that an integral study and a systematic comparison of findings of previously undertaken assessment studies is often problematic due to different analytical approaches and differences in presentation. The gradual shift from conventional assessment techniques (such as cost-benefit analysis) towards multi-dimensional assessment approaches (such as multicriteria analysis) has prompted the need for a systematic comparison of these studies, but this requires an enormous study effort and induces, as a consequence, a significant research cost. Fortunately, over the past 20 years a new set of research techniques known as **meta-analysis** has been developed which makes a rigorous analysis of study findings possible.

The purpose of meta-analysis is to summarise results from previous studies in a (preferably) quantitative way in order to allow for transferability of findings (see, for details van den Bergh et al. 1997). As a result of a more solid analytical underpinning, a synthesising process becomes thus more manageable and less vulnerable to subjective elements due to a more systematic investigation of early research findings. Voluminous study results can be analysed and the impact of ad hoc approaches on study findings can thus be reduced by the use of comparative, often quantitative methods which allow for a rigorous synthesis. These recent developments allow to establish a new type of assessment methodology for addressing multi-dimensional decision problems in a rigorous way and may lead to a significant cost reductions due to the use of previously obtained knowledge (see for an ilustration also Florax et al. 1999).

Irrespective of a specific assessment methodology, policy assessment is a procedural activity with many steps before an ultimate result is achieved. In general, we define the decision process as a set of actions and dynamic factors (behavioural, contextual) which, after a description of the problem and its alternative solutions for action has been made, leads to a specific commitment to action (Janssen 1991). A first important element in this process is the identification of the problem which does not automatically exist, unless someone perceives it as such. For example, Ackoff (1981) observes that an individual or a group can perceive a problem if, in a given choice situation, there is a difference between the present state and the desired one. This can happen when: *"(1) the individual or group has alternative courses of action available; (2) the choice of action can have a significant effect on this perceived difference; and (3) the individual or group is uncertain a priori as to which alternative should be selected* ".

Most modern policy decisions can be typified as being of a multiple objective or multicriteria type (Janssen 1991, Nijkamp and Pepping 1998, Nijkamp and Blaas 1995). This means that an optimal alternative from a set of alternatives is to be determined which best satisfies a number of -often conflicting- objectives. Another complicating factor is that on the policy level - besides a set of quantitative criteria - qualitative criteria also must be taken into account in a decision-making process. Examples are the sustainability of natural and manmade environments, the protection of school children, accessibility for the elderly generation, or the risk of criminality in public transport. Research has often resorted to social cost-benefit analysis as a proper appraisal method, and this has often been done in a successful way. However, as mentioned above, this method has severe shortcomings with regard to an operationalisation of intangible facets. In public policy evaluation, especially the study of environmental impacts turns out to be troublesome, since all advantages and disadvantages of policy options have to be translated into a common monetary unit. Hence qualitative criteria of an unpriced and intangible nature cannot be included in the decision-making procedure based on a standard social cost-benefit analysis. Within this approach, the market priorities are reflected in the (corrected) market prices or through the willingness-to-pay of the individuals (see Janssen 1991). In the practice of cost-benefit analysis, it is difficult to include incommensurable aspects of a project. Similarly, in the current practice in many countries there is hardly any applicable and meaningful way of including distributional impacts on welfare (e.g., through a weighting system for different groups) into policy evaluation, although there is in the history of cost-benefit analysis theory in economic research a vast amount of literature on distributional issues (e.g.

through weighting systems, social rates of discount, etc). Clearly, a complementary evaluation methodology that is better able to handle qualitative information in a more sophisticated way seems to be very useful for the improvement of decision-making processes.

Finally, it should be noted that a systematic comparison of evaluation case studies is – in a formal sense – not different from a policy comparison of projects or plans, so that essentially meta-analysis may also be interpreted as a special class of multi-criteria analysis methods. This will be further elaborated in the next sections in which the importance of comparing policy options in the land use and agricultural sector will be highlighted by using the above mentioned methodology.

2. The Need for a New Perspective on the Agricultural Sector

The agricultural sector is a dynamic economic sector with many conflicting issues. Agriculture has gone through cyclical movements over the past decades. In the late 1960s and early 1970s it was generally expected that agricultural production growth would be unable to keep pace with the rising needs for food by our world population. But during the mid 1970s, world food production grew rapidly, thus reducing the threat of an ever increasing gap between supply and demand. Since the late 1980s however, the optimism was tempered because of the persistent problems of insufficient food supplies in major parts of our world and the environmental and social concerns about intensive farming methods. At present there is a greater recognition of the problem of food security in the medium and long term, inter alia as a result of depletion of natural resources and of environmental and land degradation (see United Nations 1997 for more details). Against these background observations, the notion of sustainable agricultural development is quickly gaining importance (see also Lancker 1998, Nijkamp 1998).

The interest in sustainable agricultural development has grown rather rapidly after the United Nations Conference on Environment and Development in Rio de Janeiro (1992), since - in the spirit of the Brundtland Report (1987) - it was recognised that, as a consequence of the intensified use of natural resources and the rise in pollution worldwide, a greater commitment to environmental protection and sustainable development was needed. In the action programme labelled 'Agenda 21', a wide array of policy proposals and plans was laid down. The problem however, is that global recommendations need to be translated at the meso level of economic sectors and regions where different trade-offs may be made.

Consequently, the general description of sustainable development in the Brundtland Report (see WCED 1987) as a means of meeting the needs of the present without compromising the ability of future generations to meet their own needs is too abstract and too less committing to be of practical use for a balanced agricultural policy (see Nijkamp 1998). The Food and Agricultural Organisation (FAO) of the United Nations has tried to offer a more specific description of sustainable agricultural development as a development path where resource use and environmental management are combined with increased and sustained production, secure livehoods, food security, equity, social stability and people’s participation in the development process. If these conditions are fulfilled, sustainable agricultural development is environmentally non-degrading, technically appropriate, economically viable and socially acceptable, so that a maximum welfare can be achieved through a co-evolutionary strategy focussed on economic, environmental and social objectives and/or constraints on agricultural production, now and in the future (see also Pearce and Atkinson, 1993).

Conflict management is at the heart of any sustainability policy (cf. Crane et al. 1996), since there are different interests among policy-makers, among various actors and stakeholders, among population groups affected, among different regions, and even among different generations. In so far as sustainable development does not offer a normative framework for policy evaluation, it is evident that the empirical results of sustainability analysis are of a descriptive nature, or at best of a “what-if” nature.

As has already been mentioned, in the past decade the issue of sustainable development has gained importance (see for an overview of the debate Manusinghe and Shearer 1995). While it began as a policy-oriented and action-based concept to alleviate and solve global environmental change issues, it was increasingly focussed on meso - mainly sectoral - issues, such as sustainable industry, sustainable tourism or sustainable transport (see Van den Bergh 1996). Furthermore, the discussion on sustainable development has shifted towards sub-global spatial units such as sustainable regions or sustainable cities (see Capello et al. 1999, Giaoutzi and Nijkamp 1994, and Nijkamp and Perrels 1994). It has also been recognised that the distinction between strong and weak sustainability (see also Pearce and Turner 1990, and Van Pelt 1995) essentially means a spatial substitution between different categories of land use. The question here is whether and where the environmental decay of one area for a certain distinct purpose (e.g., industrialisation) may perhaps be compensated for by enhancing the environmental quality of another area (e.g., a tourist area).

The above observations are clearly exemplified in agriculture; various choice options can be imagined (such as milk production, wheat production, etc.) which cannot be undertaken simultaneously at the same place (see Barnett and Payne 1995). Furthermore, different types of intervention can be envisaged such as intensified land use, the use of pesticides, herbicides, etc. (see Douven 1997 and Simmons 1997). Consequently, the question of whether a certain agricultural land use is sustainable is a complicated one which cannot be easily answered without thorough knowledge of all trade-offs involved. Thus, space in a geographical sense has a multi-faceted nature and may serve multiple functions. The previous considerations can be further substantiated by the following observations:

- space - and thus also land use - is the **medium** (or physical market) for environmental externalities in a broad sense; this applies to global environmental change, but also to local issues like noise annoyance or soil pollution;
- space (including land) is of a **heterogeneous** nature; this means that environmental externalities have geographically discriminating distributive impacts (e.g. water pollution);
- space - and consequently also land - has both a **productive** and **consumptive** nature, so that any space consumption has welfare implications of a broader nature (including externalities); examples can be found in recreational land use and infrastructural facilities.

The above considerations do not only have a local or regional meaning, but altogether also lead to global environmental issues which impact on food supply, resource availability and climatological stability (see Cline 1992 and Fankhouser 1995). In a recent survey article by Van Ierland and Klaassen (1996), the authors identify a series of research priorities on socio-economic aspects of land use and climate change, viz. a deeper analysis of:

- agricultural impacts in developing regions;
- influence of climate scenarios on water availability in sensitive areas;
- socio-economic impacts of changes in human health;
- socio-economic impacts of environmentally induced migration;
- impacts of extreme weather events based on risk assessment;
- socio-economic impacts of changes in ecosystems and biodiversity.

Some of these concerns are long range and relate to national or international security issues such as soil erosion, chemical poisoning or nuclear waste (see also Daly and Cobb 1990). Others are more directly concerned with the daily quality of life such as water pollution, shortage of food or resources (see Homer-Dixon 1992). Another - increasingly important - issue is the emergence of natural and environmental catastrophes such as floods, landslides, long periods of drought etc. (see United Nations 1997). Events like these are difficult to predict. All such cases provoke the question of how land use (including agriculture) can be used as a vehicle for adaptation or resilience with respect to global change processes.

Sustainable agriculture is indeed concerned with proper soil management, since land (or soil) is basic factor input in this sector. In the history of economic thought, varying attention has been given to land as an economic production factor. A dominant role, for instance, was assigned to land as a basic input to the creation of economic welfare in the period of the Physiocrats. In the neoclassical world, land assumed mainly a functional economic place, as productivity and welfare differences between regions could be explained inter alia by different soil conditions (see also Giaoutzi and Nijkamp 1994). More recently - partly as a result of the emergence of ecological economics - land is regarded having a productive and a consumptive meaning within a sustainable development perspective (see e.g. Van den Bergh 1996). Furthermore, the condition of the soil has a variety of direct and indirect impacts on the quality and resilience of ecosystems impacting on biodiversity, not only locally but also globally (see e.g. Douven 1997). As a consequence of the externalities of soil pollution, we notice that soil management has become an important policy task in many countries. Soil management aims to improve the condition of the soil by actively coping with soil pollution through regulatory and market measures, by mitigating the externalities involved in soil pollution, and by seeking strategic and feasible solutions for clean-up areas (e.g., through brownfield policies).

All such conditions and strategic policies affect agricultural productivity and sustainability, and thus impact upon its growth perspective. In the present paper we will try to illustrate the differences in growth conditions in the agricultural sector in different countries by applying a recently developed method for comparative meta-analytical research, known as rough set analysis. This method will be outlined in the next section.

3. **Rough Set Analysis as a Tool for Meta-Analysis**

Meta-analysis is a research tool for comparative research. It has become an established technique in the medical and natural sciences, especially in comparative analysis of (semi-)controlled case study experiments (see, among others Van den Bergh et al. 1997, Glass et al. 1984, Hedges and Olkin 1985 and Petitti 1994). It has also been used extensively in the social sciences, particularly in experimental psychology, pedagogy, sociology, and more recently in economics (see Matarazzo and Nijkamp 1997; Nijkamp and Baaijens 1998). Meta-analysis tries to synthesise previous research findings or case studies to identify common features which might be transferable to other as yet, unexplored cases. The statistics of meta-analysis is, in the meantime, rather well developed. Especially in the case of quantitative case study results, significant progress has been made. In situations of low measurement scales (qualitative, nominal, categorical or ordinal data), meta-analysis deserves to be further developed. In the context of our comparative case study research for the productivity of the agro-food sector we are almost exclusively confronted with 'soft' data, so that standard techniques cannot be utilised. Therefore, we will in our empirical analysis utilise a fairly new method for qualitative classification analysis, known as the rough set theory (see, for details Pawlak 1991, Slowinski 1995 and Van den Bergh et al. 1997).

The basis of rough set analysis is formed by a categorical data matrix, coined the **information matrix**, in which qualitative information on attributes or performance values of case studies (objects) is systematically represented. Application of rough set analysis to this data table results in the ability to identify which possible combinations of values of attributes (measured in distinct classes) are compatible with certain ranges of a performance variable. These so-called **decision rules** are then specified as "if… then" statements, based on qualitative (essentially class) information. If certain attributes have a high frequency of occurrence in all decision rules, they tend to exert a dominant influence on the performance indicator characterising the case study concerned and hence may be considered as rather important critical success factors. If an attribute appears in all decision rules, this is the core of the impact system and may therefore be regarded as the dominant critical success factor.

Formally, we may define a rough set as a set for which it is uncertain in advance which objects belong precisely to that set, although it is in principle possible to identify all objects which may belong to the set at hand. Rough set theory assumes the existence of a finite set of objects for which some information is known in terms of factual (qualitative or numerical) knowledge on a class of attributes (features, characteristics). These attributes may be used to define **equivalence** relationships for these objects, so that an observer can classify objects into distinct equivalence classes. Objects in the same equivalence class are - on the basis of these features concerned - **indiscernible**. In the event of multiple attributes, each attribute is associated with a different equivalence relationship. The intersection of multiple equivalence relationships is called the indiscernibility relationship with respect to the attributes concerned. This intersection generates a family of equivalence classes that is a more precise classification of the objects than that based on a single equivalence relationship. The family of equivalence classes that is generated by the intersection of all equivalence relationships is called the family of elementary sets. The classification of objects, as given by the elementary sets, is the most precise classification possible on the basis of the available information.

Next, we introduce the concept of a **reduct**. A reduct is a subset of the set of all attributes with the following characteristic: adding another attribute to a reduct does not lead to a more accurate classification of objects (i.e., more granules), while elimination of an attribute from a reduct does lead to a less accurate classification of objects (i.e., less granules).

Finally, the **core** of a set is the class of all indispensable equivalence relationships. An attribute is indispensable if the classification of the objects becomes less precise when that attribute is not taken into account (given the fact that all attributes have been considered until then). The core may be an empty set and is, in general, not a reduct. An indispensable element occurs in all reducts. The core is essentially the intersection of all reducts.

Based on the previous concepts, rough set theory is now able to specify various "if… then" decision rules. For specifying such decision rules, it is useful to represent our prior knowledge of reality by means of an information table. An information table is a matrix that contains the values of the attributes of all objects. In an information table the attributes may be partitioned into **condition** (background) and **decision** (response) attributes. A **decision rule** is then an implication relationship between the description of the condition attributes and that of a decision attribute. Such a rule may be exact or approximate. A rule is exact, if the combination of the values of the condition attributes in that rule implies only one single combination of the values of the decision attributes, while an approximate rule only states that more than one combination of values of the decision attributes corresponds to the same values of the condition attributes. Decision rules may thus be expressed as conditional statements ("if then"). For further details we refer to Pawlak (1991), Slowinski (1993), Van den Bergh et al. (1997), Matarazzo and Nijkamp (1997), Baaijens and Nijkamp (1998) and Button and Nijkamp (1998). Rough set analysis will now be applied as a technical method for comparing growth rates in agriculture in different countries. This issue will be now introduced in Section 4.

4. Application to Agricultural Productivity

4. 1 Introduction

There has been a resurgence of interest in the determinants of growth directed both at isolating factors responsible for differences in growth performance and accounting for growth patterns. In particular, we observe concern about the apparent paradox of a slowdown in productivity growth in a context of a rapid development of new technologies. Our case study will concern OECD countries and therefore, we will offer first some background information on OECD countries.

Agricultural production in OECD countries grew steadily over the last two decades. De facto, it seems that productivity growth has played an important role in output growth in agriculture. Agricultural adjustment has taken place primarily in the input mix - intermediate input, land, capital and labour – rather than in total input.

Over the last 20 years the principal features of input change were the following:

- a significant increase in quantities of intermediate inputs (animal feeds, seeds, fertiliser, pesticides, animal products energy, maintenance, repairs and other services) and capital used; the increase of the volume of intermediate consumption is mainly attributable to a higher use of feed concentrates in most OECD countries, particularly where animal production increased most rapidly. With the exception of Austria, Belgium, Luxembourg, Denmark, Japan and Sweden, the use of fertilisers has increased.
- a rapid decline in labour input for all countries at an average annual rate of slightly over 2 %. The largest decline was in Spain, followed by Denmark, Finland and Austria. The rate of decline was less than 2 per cent in Australia, The Netherlands, Canada, the UK, Ireland and Greece.
- a slight reduction in land input, but less than 1% per year. In Canada and Greece land use increased by slightly over 1 % per year. Land use remained essentially unchanged in Switzerland and the UK, which implies that most changes in production over the previous two decades in the OECD countries examined were associated with increases or decreases in intensity of land use rather than changes of the farmland.

An international comparison of productivity levels (OECD 1995) shows that partial and total agricultural productivity has been larger than the corresponding economic productivity as a whole.

In contrast to various studies on productivity for the farm sector of OECD countries, there are only a few studies on productivity for the agro-food sector. Our objective is to gather existing information that is already available in this field and, after having collected this information, to use it for further comparative analysis. Table 1 summarises some of the results of studies on productivity from the literature for the agro-food sector found in an OECD study (OECD 1995). These studies refer only to a set of selected OECD countries and the indicator used here ranges from the single factor measure (e.g. labour productivity) to total factor productivity, thereby making a cross-country comparison rather difficult.

Despite differences in methodology and in results, these studies suggest that productivity growth in agro-food industries has been much less than that of the primary agricultural sector. Although these analyses provide useful information, they are subject to important limitations. For example, almost all of them use highly aggregate data and may therefore be unsuitable for assessing effects of different support policies, which in almost all cases are likely to be commodity-specific. At an aggregate level, productivity may increase or decrease because of diversification among sub-sectors. In spite of these limitations, the procedure adopted in the next section permits us to explore the data from these previous studies as a *primary analysis* in order to select and screen the existing information. The results obtained might then eventually be utilised in a *secondary analysis* which is essentially a re-analysis of data that were previously used.

4.2 Decomposition of the data - data analysis

In this section a rough set analysis of the data given in Table 1 will be performed. This is done by initially classifying the outcomes of all variables by defining a codification for all attributes. All attributes and their values are now listed below. We will utilise the following condition attributes:

a1 – Country
a2 - Sector coverage
a3 - Method used
a4 - Time period: starting point
a5 - Time period : length

The domains of these attributes have been coded as follows:

Country:

1 - Canada, Australia and USA;
2 - Large European countries: UK, Germany, Italy and France
3 – Japan
4 - Small European countries: Denmark, Finland, Netherlands, Sweden, Norway and Belgium

Sector coverage:

1 - food
2 - beverages
3 - manufacturing
4 - food and beverages
5 - food, beverages and tobacco
6 - agriculture

Method used:

1 - index number
2 - econometric cost function
3 - econometric production function
4 - input-output analysis
5 - Cobb-Douglas production function
6 - Solow growth accounting method
7 - labour productivity

Time period

Starting point:

1 - 1950
2 - 1960
3 - 1970
4 - 1980

Length:

1 - 10 years
2 - 20 years
3 - 30 years

The decision attribute D (i.e., the endogenous variable) represents the *average percentage change* in productivity which has been codified in the following four classes:

1 - less than 1%
2 - between 1% and 2%
3 - between 2% and 3%
4 - more than 3%

Table 2 offers a presentation of the results for the 50 case studies examined, and can be treated as a knowledge information system in which *a1*, *a2*, *a3*, *a4* and *a5* are the condition attributes and *D* represents the decision attribute. The problem to be dealt with here can now be analysed in two different steps:

1) reduction of knowledge
2) checking the consistency of this knowledge.

Reduction of knowledge consists of releasing all dispensable condition attributes and condition attribute values from the table. Practically, we have to check whether it is possible to eliminate some of the elementary condition attributes in Table 2. To this end, we computed the core in Table 3 - the set of all indispensable values - of the information system. The core in our example consists of the attributes a1, a2, a3, a4 (country, sector, method used, and starting point of the studies selected). This means that it is not possible to eliminate these attributes without disturbing the ability of the system to classify objects. Table 4 shows that many objects have the same description (atoms); there are thus identical objects and hence, they can be removed from the table.

Consistency of knowledge in our example is intended to discover the functional dependency between the condition attributes on the one hand, and the average change in productivity growth in the agro-food sector on the other. Therefore, we now move on to the analysis of the observed data describing the set of studies selected, in order to obtain a classification decision algorithm. From a decision table a set of decision rules can be derived. The rules are logical statements ("if…then") which represent the relationship between the description of objects and their assignment to particular classes. The set of decision rules for all decision classes is called a decision algorithm.

As a next step in our analysis we aim now to identify some lessons based on learning principles. Recently research in machine learning - as an area of artificial intelligence - has been rather intensive. Particularly in similarity-based learning systems, learning is based on establishing similarities between positive examples which represent the same concept (class), and dissimilarities between positive and negative examples, representing different concepts. Similarity-based learning is also called empirical learning in order to emphasise the fact that it is based on the act of inducing underlying knowledge from empirical data. The goal of machine learning, for example, is to find a discriminating description of the class considered. Thus the task is to include all positive examples from the concept at hand in the description of this concept and to exclude the complementary set containing all negative examples from the description.

In the experiment presented in this paper a rule induction system called learning from examples (LERS) was used. LERS uses an approach to an inconsistent data set based again on rough sets. First, LERS checks the input data for consistency. If data are inconsistent, for every class two sets are computed: a lower and upper approximation for each class, i.e. decision attributes. Rules are then induced separately from both sets. Rules induced from lower approximation are called *certain* rules and from upper approximation are called *possible* rules. The terminology introduced in Gzymala-Busse (1988) is based on the following observation: if a case is a member of the lower approximation of the class, it is a certain member of the class. Similarly, if a case is a member of the upper approximation, then it is only a possible member of the class. This means that the system

Table 1. Studies of productivity growth in the agro-food sectors of the OECD countries

N.	***Country***	***Sector coverage***	***Method***	***Time period***	***Average % change***
1	Canada	Food	Index number	1961-86	0.37
2	Canada	Beverage	Index number	1961-86	0.56
3	Canada	Manufacturing	Index number	1961-86	1.40
4	Canada	Food and Beverage	Index number	1962-85	0.40
5	Canada	Manufacture	Index number	1962-85	0.80
6	Canada	Food and Beverage	Econometric cost function	1961-82	0.10
7	Canada	Food and beverage	Econometric production function	1961-82	0.36
8	Canada	Food	Econometric cost function	1961-79	0.47
9	Canada	Food and Beverage	Index number	1962-77	0.35
10	Canada	Food and Beverage	Econometric cost function	1962-75	-0.20
11	Australia	Food, Beverage and Tobacco	Econometric production function	1976-90	0.67
12	UK	Food	Input-output	1954-63	1.70
13	UK	Food	Input-output	1968-74	1.14
14	UK	Agriculture	Input-output	1979-84	-1.19
15	UK	Agriculture	Input-output	1954-63	1.84
16	UK	Agriculture	Input-output	1968-74	0.84
17	UK	Agriculture	Input-output	1979-84	1.13
18	UK	Food	Econometric production function	1979-86	3.90
19	UK	Drink	Econometric production function	1979-86	7.60
20	UK	Manufacturing	Econometric production function	1979-86	3.70
21	US	Food	Index number	1958-82	0.28
22	US	Food	Index number	1958-72	0.28
23	US	Food	Index number	1972-82	0.29
24	Australia	Food, Beverage and Tobacco	Cobb-Douglas production function	1976-90	0.40
25	US	Food	Index number	1950-77	0.007
26	US	Food	Index number	1950-72	0.074
27	US	Food	Index number	1972-77	-0.418
28	Italy	Food	Solow's growth accounting method	1960-85	2.73
29	Canada	Food	Solow's growth accounting method	1960-85	1.10
30	Germany	Food	Solow's growth accounting method	1960-85	2.46
31	UK	Food	Solow's growth accounting method	1960-85	5.34
32	US	Food	Solow's growth accounting method	1960-85	2.31
33	Japan	Food	Solow's growth accounting method	1960-85	2.85
34	Italy	Food	Labour productivity	1970-80	5.1
35	Italy	Food	Labour productivity	1953-63	4.6
36	Australia	Food	Labour productivity	1980-85	1.11
37	Austria	Food	Labour productivity	1980-85	1.18
38	Belgium	Food	Labour productivity	1980-85	1.32
39	Canada	Food	Labour productivity	1980-85	1.17
40	Denmark	Food	Labour productivity	1980-85	1.10
41	Finland	Food	Labour productivity	1980-85	1.10
42	France	Food	Labour productivity	1980-85	1.02
43	Germany	Food	Labour productivity	1980-85	1.18
44	Ireland	Food	Labour productivity	1980-85	1.46
45	Italy	Food	Labour productivity	1980-85	1.08
46	Japan	Food	Labour productivity	1980-85	1.02
47	Netherlands	Food	Labour productivity	1980-85	1.25
48	Norway	Food	Labour productivity	1980-85	0.65
49	Sweden	Food	Labour productivity	1980-85	1.06
50	UK	Food	Labour productivity	1980-85	1.30

Table 2 Information system after codification

Objects	A1	a2	*a3*	a4	a5	*D*
1	1	1	1	2	3	1
2	1	2	1	2	3	1
3	1	3	1	2	3	2
4	1	4	1	2	3	1
5	1	3	1	2	3	1
6	1	4	2	2	3	1
7	1	4	3	2	3	1
8	1	1	2	2	2	1
9	1	4	1	2	2	1
10	1	4	2	2	2	1
11	1	5	3	3	2	1
12	2	1	4	1	1	2
13	2	1	4	2	1	2
14	2	6	4	3	1	1
15	2	6	4	1	1	2
16	2	6	4	2	1	1
17	2	6	4	3	1	2
18	2	1	3	3	1	4
19	2	2	3	3	1	4
20	2	3	3	3	1	4
21	1	1	1	1	3	1
22	1	1	1	1	2	1
23	1	1	1	3	2	1
24	1	5	5	3	2	1
25	1	1	1	1	3	1
26	1	1	1	1	3	1
27	1	1	1	3	1	1
28	2	1	6	2	3	3
29	1	1	6	2	3	2
30	2	1	6	2	3	3
31	2	1	6	2	3	4
32	1	1	6	2	3	3
33	3	1	6	2	3	3
34	2	1	7	3	2	4
35	2	1	7	1	2	4
36	1	1	7	4	1	2
37	4	1	7	4	1	2
38	4	1	7	4	1	2
39	1	1	7	4	1	2
40	4	1	7	4	1	2
41	4	1	7	4	1	2
42	2	1	7	4	1	2
43	2	1	7	4	1	2
44	4	1	7	4	1	2
45	2	1	7	4	1	2
46	3	1	7	4	1	2
47	4	1	7	4	1	2
48	4	1	7	4	1	1
49	4	1	7	4	1	2
50	2	1	7	4	1	2

Table 3 Accuracy and quality of classification of the decision variable

Class of decisional/ dependent variable	Accuracy	Lower approximation number of objects	Upper approximation number of objects
1	0.5862	17 *{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 16, 17, 21, 22, 23, 24, 25, 26, 27, 37, 38, 40, 41, 44, 47, 48, 49}*	29 *{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 16, 17, 21, 22, 23, 24, 25, 26, 27, 37, 38, 40, 41, 44, 47, 48, 49}*
2	0.4167	10 *{12, 13, 15, 36, 39, 42, 43, 45, 46, 50}*	24 *{3, 5, 12, 13, 14, 15, 17, 29, 32, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51}*
3	0.1667	1 *{33}*	6 *{28, 29, 30, 31, 32,33}*
4	0.6250	5 *{18, 19, 20, 34, 35}*	8 *{18, 19, 20, 28, 30, 31, 34, 35}*

Accuracy of classification: 0.4925
Quality of classification: 0.6600
Core of attributes: 1, 2, 3, 4

Table 4 Reduced information system

Objects	a1	a2	*A3*	A4	a5	*D*
1	1	1	1	2	3	1
2	1	2	1	2	3	1
3	1	3	1	2	3	2
4	1	4	1	2	3	1
5	1	4	2	2	3	1
6	1	4	3	2	3	1
7	1	1	2	2	2	1
8	1	4	1	2	2	1
9	1	4	2	2	2	1
10	1	5	3	3	2	1
11	2	1	4	1	1	2
12	2	1	4	2	1	2
13	2	6	4	3	1	1
14	2	6	4	1	1	2
15	2	6	4	2	1	1
16	2	1	3	3	1	4
17	2	2	3	3	1	4
18	2	3	3	3	1	4
19	1	1	1	1	3	1
20	1	1	1	1	2	1
21	1	1	1	3	2	1
22	1	5	5	3	2	1
23	1	1	1	3	1	1
24	2	1	6	2	3	3
25	1	1	6	2	3	2
26	3	1	6	2	3	3
27	2	1	7	3	2	4
28	2	1	7	1	2	4
29	1	1	7	4	1	2
30	4	1	7	4	1	2
31	2	1	7	4	1	2
32	3	1	7	4	1	2

induces a set of sufficient rules completely describing every class, although only some attribute pairs are involved in the rules concerned.

The intriguing question is now how to use the set of rules for a classification of new cases on productivity growth in the agro-food sector of OECD countries. For example, in a transferability question we may wonder how to use these two rules sets for a classification of new studies, and which rule induction system may be useful in the selection or choice of individual studies for the analysis concerned by means of a minimal description of a class.

Table 5 contains the guideline we should follow to select new studies. The basic aim is to retrieve knowledge by observing previous studies; this recorded knowledge can be used for the generation of a reduced algorithm, so that it is next possible to classify further studies on the productivity growth of the agro-food sector.

Table 5 Inference rules based on learning from examples

Rule nr.	a1	a2	*a3*	a4	a5	**D**	**Strength**	**Objects**
1		4				1	5	4, 6, 7, 9,10
2		5				1	2	11,24
3		1	1			1	7	1,21,22,23,25,26,27
4		2	1			1	1	2
5		1	2			1	1	8
6	2	6	4	2		1	1	16
7	1	3	1	2	3	1 or 2		5(class1); 3 (class2)
8	2	6	4	3	1	1 or 2		14 (class1); 15 (class2)
9	4	1	7	4	1	1 or 2		48(class1);37,38,40,41,44,47,49(class2)
10		1	4			2	2	12, 13
11	1	1	7			2	2	36, 39
12	3	1	7			2	1	46
13	2	6	4	1		2	1	15
14	2	1	7	4		2	4	42, 43, 45, 50
15	1	1	6	2	3	2 or 3		29(class2); 32(class3)
16	3		6			3	1	33
17	2	1	6	2	3	3 or 4		28,30(class3); 31(class4)
18	2		3			4	3	18, 19, 20
19	2		7	3		4	1	34
20	2		7	1		4	1	35

4.3 Empirical results

The final step of our data analysis is the identification of a classification algorithm which permits us to make conditional predictions (‘if then’) on the basis of the accumulated knowledge in new situations (see Table 5). Here we have used a classification related to the construction of a classification algorithm that, on the basis of the current knowledge, can be applied to a number of cases to classify objects previously unseen. Each new object in the future can then be assigned to a class belonging to a predefined set of classes on the basis of observed values of properly chosen attributes (features).

The algorithm may also be used for the classification of new objects. It should be noticed that not all decision rules are equally important or reliable. Some rules are formulated by using information about a larger number of objects than other rules. This difference in importance in derived rules can be described by an additional parameter for each rule. Different parameters (i.e. support, strength, relative strength, length) can be used to quantify the *quality of the rules* generated. In addition, the *strength* can be used as a system to simplify a decision table.

In our experiment this method has been used in an attempt to make a selection of the rules. For example when regarding the consistent rules, we can easily notice that not all statements are meaningful, because only the rules 1, 3, 14 and 18 are supported by a consistent number of objects.

In particular, in case of classification 1, which expresses an average change in productivity growth for the agro-food industry, two strong decision rules were obtained. According to rule 1, if we would like to classify a study in the agro-food field and if the attribute "sector" analysed is "food and beverages", we can expect the average change to be rather low, since that sector comprises approximately less than 1% of the growth productivity.

Rule 3 represents a different case: here the two attributes "sector" and "method" are included. This means that it is impossible to predict in which combination the attribute "food" has to be considered without including the attribute "index number".

With regard to class 2, which is related to an average growth falling in between 1% and 2%, we can select rule 14 as being supported by four objects. In this case the attributes to be considered together in further studies are related to the "large European countries" (UK, Germany, Italy and France), the "food" sector, "labour productivity" as the method used and the year "1980" as the starting point of the analysis.

More burdensome is the case of class 3, for which we obtained only one rule supported by only one object. However, some generalisations can be made. For example, it is possible to notice in rule 16 that we should consider the attributes "Japan" and the Solow growth accounting method to account for an average rate of growth between 2% and 3%.

Finally, for class 4 we have selected rule 18, for which "large European countries" and the "econometric production function" should be used to classify a new study with the highest (more than 3%) growth average in the agro-food sector in OECD countries.

The strength of a rule has a particular meaning for non-deterministic decision rules. In this case, if the *strength* of one category is higher than the *strength* of other categories occurring in the non-deterministic rule, one can conclude that according to this rule, the object considered most likely belongs to the strongest category. In our example, since non-deterministic rules 7, 8, 15 and 17 are supported by only one or two objects for each class, we have assumed that they are at the end not significant enough to offer a guideline for further studies. Instead, concerning rule 9 we can conclude that the presence of new studies, in which the considered attributes are "small European countries", "beverages", "labour productivity", "starting from 1980" and covering "10 years", can be associated with class 2 (an average change between 1% and 2% growth).

5. Conclusion

The present paper has offered an introduction into the use of modern assessment methods for multidimensional planning issues. Particular attention has been given to the potential of multi-criteria analysis. It was argued that meta-analysis may be regarded as special case of multi-criteria analysis. In particular in case of soft information, the use of rough set analysis turns out to be of great importance. The numerical application has demonstrated that this new approach is able to identify interesting patterns in qualitative data, which may explain the performance of certain policies. An important issue to be developed in future research is the question of generalizability or transferability of findings from quantitative information. In this context, also alternative classification methods may have to be considered (e.g. discriminant analysis, fuzzy set analysis).

The authors have worked together on the subject of this paper and they are jointly responsible for the paper as a whole. However, P. Nijkamp is primarily responsible for sections 1, 2 and 3 and G. Vindigni for sections 4 and 5.

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