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EXPERTISZE, A TOOL FOR DETERMINING THE EFFECTS OF SOCIAL SECURITY LEGISLATION

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Summary

Social security legislation plays an important role in the Dutch society. In view of this, the effects of social security legislation have to be analysed carefully before new legislation can be made. Due to the growing complexity of legislation on the social security domain, this analysis has become a demanding task. ExpertiSZe is a knowledge-based system developed to support the process of analysing juridical and socio-economic effects of social security legislation. The ExpertiSZe system consists of three modules: a consultation module, a consistency module and a simulation module. These modules, which all work on the basis of the same rule-based model, provide the legislator with more insight into the impact of legislation. This article describes the potential of ExpertiSZe to support the analysis of effects of legislation.

1. Introduction

Social security legislation has a great impact on Dutch society. In the Netherlands about 4.5 million people are more or less dependent on the social security system. The expenditure for this system now amounts to 140 thousand million guilders, which is about 30% of the Dutch nett national income [Petersen et al., 1990]. In view of both the importance to individuals as well as the total costs involved with the social security system it is important that the government has adequate information about the actual effects of legislation on the social security domain. Before decisions about new legislation can be made these effects have to be carefully analysed. The last decade social security legislation has become increasingly complex [Overhoff & Molenaar, 1991]. Because of this it is difficult for the government to get insight into the effects of legislation on the social security domain.

ExpertiSZe is a knowledge-based system which supports the legislator in acquiring information about the effects of social security legislation. ExpertiSZe was designed by the University of Twente during the period 1988-1990. This development took place under the auspices of the Ministry of Social Affairs and Employment. ExpertiSZe is intended as a research tool to investigate the possibilities of knowledge-based support in analysing social security legislation.

The ExpertiSZe prototype, which was completed in 1990, consists of three modules. The consultation module gives the legislator insight into the effects of an act of legislation when that act is applied to a single case. The consistency function applies an act to large volumes of theoretical cases, automatically generated by the consistency function. The simulation module gives, in combination with actual case data, more insight into the macro-economic effects of a social security act [Van 't Eind et al., 1990][Nieuwenhuis, 1989][Svensson & Wassink, 1990].

In this article we present some of the possibilities of ExpertiSZe to support the analysis of legislation. For this purpose, we start describing how in ExpertiSZe a model of the social security legislation is made. Once the modelling is complete, the knowledge base can be processed by all three modules of ExpertiSZe.

2. Modelling legislation in an ExpertiSZe knowledge base

The ExpertiSZe system provides the user with insight into the effects of social security legislation. In order to do so the system needs to have a model of that legislation. This model, in the knowledge-based approach called a “knowledge base”, contains a representation of the text of the legislation. Once the model has come into being it can be used in a process of automated reasoning.

In ExpertiSZe the modules are tailored to the same type of knowledge base. As a result, a knowledge base can be processed by all three modules. This has been the most prominent design issue in the development of ExpertiSZe.

Hence, it is important that the ExpertiSZe knowledge base contains an accurate representation of the text of the legislation. If, during the process of modelling, errors or misinterpretations of the text are introduced into the knowledge base, the results given by ExpertiSZe will not resemble the factual effects of the represented legislation.

In order to minimize the chance of errors and misinterpretations in the knowledge base, we try to realize a one-to-one (isomorphic) representation of the text of the legislation. This representation technique was introduced during the development of the knowledge-based system TESSEC [Nieuwenhuis, 1989]. A one-to-one representation aims at corresponding as closely as possible to the text of the legislation, in sofar as form and contents are concerned.

The one-to-one representation has shown to be a useful approach for modelling legislation. Apart from leading to sound models, this modelling technique also has two other advantages regarded as important for the ExpertiSZe-project. These advantages are:

* the clarity of the models making it easy to discuss them with legal experts;
* the ease of translating changes in legislation into changes in the model.

In ExpertiSZe the legislation is represented in the knowledge base by making use of the Knowledge Representation Language KRL [Nieuwenhuis, 1989]. KRL is based on production rules.

In order to make the ideas about modelling legislation behind ExpertiSZe more understandable, we will show in an example how a small piece of fictitious legislation is represented in KRL. This example will also be used to illustrate the working of the consistency module.

2.1. Two fictitious sections for course subsidies

A ministry has been ordered to design new legislation with regard to course subsidies. The new legislation should enable unemployed people to attend courses in order to improve their chances on the labour market. After some time the following fictitious sections are proposed:

§ 99
In addition to the normal unemployment benefit an educational subsidy is given in the following circumstances:
1. If the client is a Dutch unemployed citizen

2. If the client is a foreigner living in the Netherlands and the subsidy as determined by section 99a would be more than ƒ 100,-

§ 99a
The amount of the educational subsidy is based on the total course fee:
1. The subsidy for courses with a fee less than ƒ 500,- is 30% of this fee.
2. For courses with a fee of more than ƒ 500,- a subsidy of 20% of this fee is given.

To be able to analyse sections 99 and 99a with the modules of ExpertiSZe, the two sections are represented in the knowledge base with the aid of KRL, thereby using the one-to-one approach. This leads to the following model:

```
OUTPUT      result

   99/1     IF     client_is_dutch
                   AND client_is_unemployed
            THEN   gets_a_subsidy = TRUE

   99/2     IF     NOT client_is_dutch
                   AND living_in_holland
                   AND subsidy > 100
            THEN   gets_a_subsidy = TRUE

   99a/1    IF course_fee < 500
            THEN  subsidy = 0.30 * course_fee

   99a/2    IF course_fee > 500
            THEN subsidy = 0.20 * course_fee

   extra/1  IF gets_a_subsidy = TRUE
            THEN result = subsidy
            ELSE result = 0.
```

For the purpose of explanation the above rules are presented in a simplified and translated form. The actual Dutch KRL language is more elaborate.

Looking at this example, we notice that each sentence in the legislation has led to one (IF...THEN...ELSE) statement in the model (the principle of one-to-one representation). Another notable point is the fact that the last statement, about the output parameter 'result', had to be added to enable the model to reach a conclusion.

3. Consistency testing in ExpertiSZe

Social security legislation in the Netherlands contains many sections with prescriptions about how to decide in individual cases on a benefit. Although the role of these prescriptions in practice is a topic for lengthy discussions, it is generally accepted that the prescriptions as given by the central government should comply at least with the following two demands:

a. the legislation must provide useful and feasible guidelines for the actual decision-making process in practice and must therefore contain *clear prescriptions;*
b. the legislation should lead to the right decisions, and therefore it has to contain *right prescriptions*.

3.1. Clear prescriptions: the requirement of internal consistency

The demand of clear prescriptions is a demand with widespread implications. Aspects of legislation to be addressed in this context are, for instance, the appropriate use of the dutch language and the structure of prescriptions in the legislation [Allen, 1987]. This paper concentrates on the structure of the prescriptions. With regard to this internal structure, the requirement of internal (logical) consistency can be placed upon legislation. In the ExpertiSZe project the idea of internal consistency is translated into three types of requirements that are used to evaluate legislation [Svensson & Nieuwenhuis, 1990] [Kordelaar & Wassink, 1991]:

* *Completeness of the prescriptions*: for every possible configuration of input parameters, the legislation has to provide rules for determining the values of the output parameters.
* *Solubility of the prescriptions*: the prescriptions should unambiguously lead to a solution.
* *Lack of redundancies*: all elements in the prescriptions should have a function in the decision making process.

ExpertiSZe helps to search the legislation for prescriptions that do not comply with these three requirements. This is performed during the modelling of the legislation into the knowledge base and also thereafter while compiling the knowledge base. At the representation stage ExpertiSZe gives support by means of the KRL language. KRL is a formal language. The representation of legislation in a formal language requires a greater precision than the representation of that legislation in natural language. The individual modelling legislation in KRL has to make the content of that legislation explicit and clear. If it is not possible to represent legislation in KRL, this may be an indication that the legislation is defective.

Once the legislation has been represented in KRL, the knowledge base is compiled. When compiling, ExpertiSZe searches the knowledge base for possible defects which may indicate defects in the legislation. During the compilation three tests are carried out:

a. a *completeness* test, which searches for lacunae and which consists of two subtests:
   * a test on the completeness concerning parameters determining, for all the parameters, whether it is clear how they should be ascertained;
   * a test on the completeness of the rule set determining whether the available rules guarantee that the output parameters get a value assigned under every possible input configuration.

b. a *redundancy* test which also consists of two subtests:
   * a test on redundant parameters determining whether a parameter defined by the legislation is actually used elsewhere;
   * a test on redundant rules determining for each rule whether it plays a role in arriving at the results of that legislation.

c. a test on *reasoning loops*; it uses the production rules in the knowledge base to generate a dependency graph (the nodes of this graph represent parameters and the arcs represent relationships between them) and then searches for cycles in this graph.

An example:
When compiling the model of the course fee ExpertiSZe generates a list of parameters which are mentioned in the legislation. If the legislation gives no rules the task is to determine them: "client_is_unemployed", "client_is_dutch", "course_fee", "living_in_holland".
This list of parameters can be submitted to the legislative experts, in order to let them decide on the need of further information about these parameters in the legislation. The availability of the generated list thus helps avoiding lacunae.

3.2. Right prescriptions: the requirement of external consistency

The other demand formulated is that legislation should contain right prescriptions, leading to right decisions. The rightness of legislation has to do with its relationship with the environment, i.e., the society in which the legislation applies and other existing legislation with which it has to agree. From this environment one can derive many external requirements with which legislation has to comply. A few examples are:

* legislation must lead to the achievement of the purpose for which it was designed [Bench-Capon, 1987]. Moreover, it should not result in unwanted side-effects (e.g., infringement of the right of privacy);
* legislation should be in accordance with the principle of equality as stated in the law, which implies that similar cases should receive similar treatment, and that unsimilar cases should be treated differently to the degree of their dissimilarity;
* a law must not be in conflict with other provisions, such as the Dutch Constitution and international regulations;
* a law may not be in conflict with the norms of ethics and decency prevailing in society.

The complete range of external requirements is large and these requirements cannot easily be divided into categories. What types of external requirements can be placed upon legislation is still under investigation. The current consistency module in ExpertiSZe is built to provide the legislator with an overview of all the individual decisions that can be made according to a given act. Based on the model of the act, the consistency module automatically generates all possible input configurations and determines the decisions for each of them. External inconsistencies can then be found by testing the output against a list of external requirements. At this stage of research we have come upon many pieces of evidence that the consistency module indeed provides possibilities for analysing legislation [Kordelaar & Wassink, 1991]. The principle is outlined below and illustrated with two examples.

3.2.1. Example of a simple test on external consistency

Suppose there are two Boolean input parameters A and B, an intermediate numerical parameter C and a numerical output parameter D. These parameters have relations adequately described by the following production set:

```
IF A                   THEN C = 0
IF NOT A AND B         THEN C = 1
IF NOT A AND NOT B     THEN C = 2
IF A                   THEN D = C
IF NOT A               THEN D = 2 * C
```

The following external requirement is placed upon the outcomes of the production set: D should never be an odd number.
Using the production set, ExpertiSZe generates automatically the following decision table of input and output parameters:

A	B	D
T	-	0
F	T	2
F	F	4

Legend:
T = True
F = False
- = value is unimportant

In analysing the results, we see that the requirement on D is never violated. All the possible cases have been generated and none of the outcomes for D proves to be odd (notice that "C" is not mentioned in this table because it is only an intermediate parameter).

3.2.2. Elaboration on the example

People working in the field of Artificial Intelligence may have objections to this example. They may argue that the example is simple and does not show the problems that can be expected when using more complex production sets. Then, the number of possible input configurations is considered to grow rapidly due to:

* the appearance of multi-valued input parameters (e.g., if a rule states "all educational costs are subsidized for 50%", we can no longer generate every possible case because the input parameter "educational cost" can adopt an infinite number of values), and
* combinatoric explosion (if we combine two Boolean parameters we can make four possible combinations, if we combine three we get eight, ten factors result in 1024, etc.).

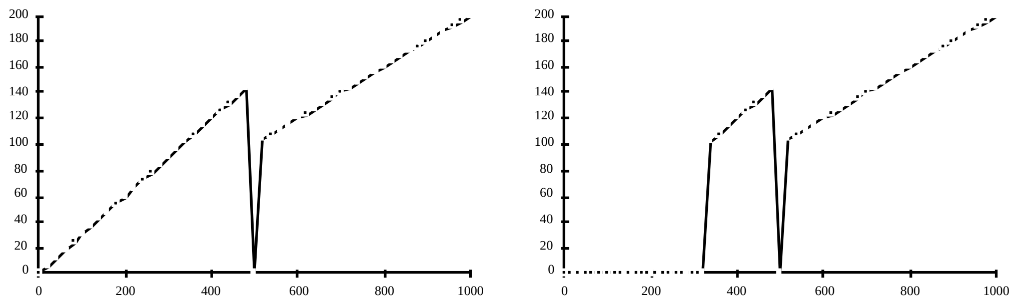
ExpertiSZe treats these problems adequately.
As a first solution ExpertiSZe gives the user the possibility to determine which values should be considered as input values for each parameter. This enables the consistency checking of models which contain multi-valued parameters (although it is true that it also reduces the power of the test because one might "jump" over an interesting input value).
As a second solution ExpertiSZe performs an automatic reduction of the input configurations by only generating the relevant cases. This number of relevant cases is dependent on the model, and is often far less than the number that could be expected as a result of combinatoric explosion (as shown in the example above, the "rule" of combinatoric explosion would lead us to expect four cases, but in fact only three cases are relevant).

3.2.3. Example of a more realistic test on external consistency.

If we take the example of the educational subsidy, we might, for instance, define the following external requirements:

* more expensive courses should lead to higher subsidies (the legislation should describe a monotonous non-decreasing function);
* there is a maximum subsidy to prevent the government from overspending;
* with the increase in the course price the costs for the participant should also rise.

The user can tell ExpertiSZe to make a table for all cases with educational costs between *f* 0.00 and *f* 1000.00, thereby taking steps of *f* 20.00. ExpertiSZe then automatically generates (see Figure 1). A numerical table which can be transformed into a graphical representation.



The two graphs represent the effects for two different groups: for Dutch unemployed citizens (left) and for foreigners (right).

Figure 1: The educational subsidy (vertical) as a function of the course fee (horizontal).

Figure 1 shows several points where the legislation violates the requirements.

* The first requirement (more expensive courses should lead to higher subsidies) is violated for both graphs on the trajectory for course fees between ƒ 400,- and ƒ 600,-. We see that courses with a fee of ƒ 450,- lead to a higher subsidy than courses with a fee of ƒ 550,-. Furthermore, several jumps in the graphics show that it is not a monotonous, non-decreasing function.
* The second requirement (there should be a maximum subsidy) is probably violated, because there is no evidence that the subsidy is kept below a certain maximum.
* The third requirement is violated for foreigners, since for them a course of ƒ 320,- is not subsidised and thus costs ƒ 320,-, while a course of ƒ 450,- only costs them ƒ 300,- (ƒ 150,- is subsidized).

4. Determining the socio-economic effects

When an act is changed, the change generally has an impact on the level of individual decisions. However, the micro impacts on all individuals together will also result in aggregated socio-economic effects (effects for groups, and effects for the total population). Insight into these socio-economic effects is of great importance for the policy maker. In this section we present the micro-simulation module of ExpertiSZe that supports this aspect of evaluation of legislation.

4.1. Problems in the determination of socio-economic effects

The determination of the socio-economic effects of a social security act is not an easy task. The most important problem encountered is the fact that social security legislation is generally formulated in a form which enables micro-level decisions. The legislation describes what benefit an individual should obtain under specific, individual, conditions. The socio-economic effects on the aggregated level result indirectly from the repeated application of the legislation to all individuals in the population.

In order to determine the socio-economic effects of an act it is necessary to find a way to combine the information on changes in legislation with the information on the population to which this legislation is applied. Three general approaches, that can be used to combine the relevant information, are:

* combining the information on a macro level, which requires the translation of an act into certain macro parameters (such as estimated mean benefit); these parameters can then be related to the relevant population parameters in order to obtain the desired outcome;
* combining the information on a meso level, which requires the translation of an act to parameters for specific socio-economic clusters (e.g., the mean benefit for married couples and the mean benefit for bachelors). These parameters can then be related to information about these clusters in order to determine their effects, which eventually can be used to estimate the effects for the total population;
* combining information on a micro level, which requires the act to be represented on a micro level. When using a representative sample of individuals, these individual effects can later be aggregated to produce estimates for the total population. This third approach is generally known as micro-analytic simulation and was first proposed by Orcutt [1957].

Although the macro and meso approaches work reasonably well in many cases these methods have one serious defect: the legislation as defined on a micro level has to be translated to the appropriate level before it can be used. It is found that for more complex cases (and many changes in legislation are complex) this translation is almost impossible. For those cases, a micro approach is the only possible solution [Van 't Eind et al., 1990]. In spite of this fact, in practice the micro approach is hardly used. The first reason is that the amount of data, needed to perform micro simulations is generally not available. The second reason is that, so far, the ministry has not set aside any means to develop accurate micro models of legislation.

4.2. A knowledge-based micro-simulation approach?

At this point of our research we have posed the question: is it possible to make a micro-simulation program that uses the knowledge-based models designed so far?

This question has led us to the development of an additional module for *static micro simulation*. The ideas behind this module are as follows (see Figure 2):

* the models contended so far enable us to draw conclusions about the impact of an act on a specific case;
* information about a large number of individual cases can be stored in a database;
* when taking individual cases from a database one at the time and determining the outcome of the application of the model to each case, we are able to use the micro-level approach for determining macro effects of legislation.

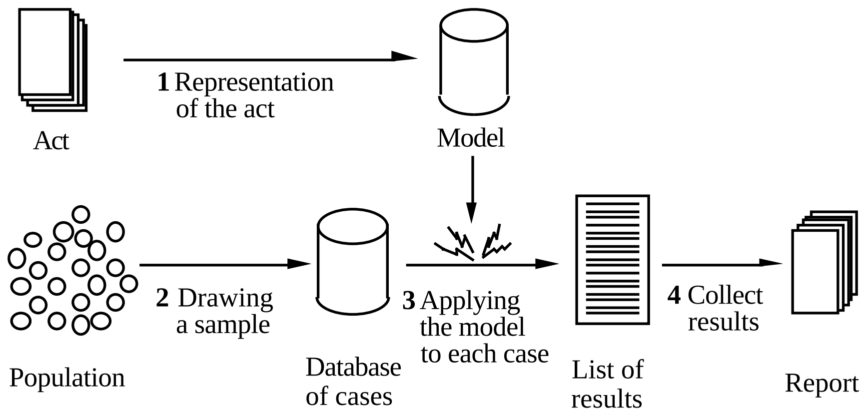


Figure 2: The principle of knowledge-based simulation

The idea of micro simulation as shown in figure 2 yields some problems to be discussed. The first problem to arise is that of the availability data [Svensson & Wassink, 1990]. In order to work with a micro-simulation method as proposed, a large amount of data about individuals is needed. When gathering these data many problems may emerge (e.g., privacy aspects).

The second problem is that populations are not static but constantly changing systems. It is therefore impossible to predict precisely what will happen in the future, especially when using a single sample that was taken in the past.

The third problem has to do with the possibility of indirect effects. Changes in legislation may cause indirect effects that cannot be determined by a static approach. An example of such an indirect effect is behavioural response, the fact that people are not unaware of changes in legislation and may react on them. Behavioural response can lead to important changes in the population, with as a result that the old sample is not representative anymore. In fact, changes in legislation sometimes augment the behavioural response rather than the direct effect shown in the legislative text (e.g., fines are not meant to let people pay some money each time they commit an offence; they are intended to change or prevent undesired behaviour).

4.3. Experiments with the simulation method

For a better insight into the usability of the micro-simulation technique, several experiments were conducted, using an existing model of the Dutch National Assistance Act (ABW). A validation experiment in which administration data from a local social security centre were used to feed the model, showed that the results given by ExpertiSZe are comparable with the actual decisions on these cases (see Figure 3). The linear correlation between model and real benefits turned out to be 0.95.

In other experiments, in which other data sources were used, the level of correlation was not quite as high, but still encouraging. The correlations found in two experiments on survey data are: .89 and .78.

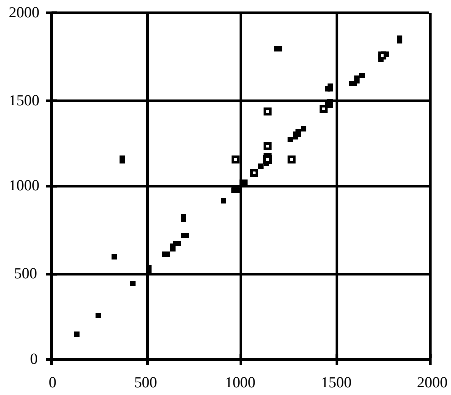


Figure 3: Model benefits (vertical) as a function of the real benefit (horizontal); n = 101

Next to the correlation found the use of knowledge-based micro-simulations has other important advantages.

Experiments with our model of the current national assistance act, showed that the simulation module is not only a good tool to establish endresults (such as the average benefit), but also to analyse different aspects of the legislation. Because of the one-to-one correspondence between model and legislation, the knowledge-based micro-simulation is especially useful for determining the impact of different sections in the act.

Figure 4 shows the output of a simulation that provides some insights into the effects of an act. It explains how different sections of the act contribute to the total benefit. It also gives the division of the population into the three main sub-populations defined by the act (couples, singles and single parents).

Micro simulation analysis:

Model: ABW (July 1990)
population: Rww
Sample size: 1000 (generated fictitious sample)

Benefit and composition

	Total	Benefit base	Housing addition	Income deduction	Housing deduction
Sections		3,4,5	6,10	11	10

mean	1,092.03	1,177.39	38.52	48.82	30.32
st. dev.	383.58	280.40	83.15	157.26	77.15
minimum	0.00	370.01	0.00	0.00	0.00
maximum	2,031.42	1,611.37	470.55	1,024.77	300.99

Distribution of main types of clients

couples:	22.3%
singles:	72.0%
single parents:	4.0%

Figure 4: Results from knowledge based micro simulation

5. Concluding remarks

In this article we have discussed how ExpertiSZe supports the analysis of effects of social security legislation. We have shown that ExpertiSZe is able to give several forms of support, all based on one type of model. This model is constructed according to the principle of a one-to-one representation of the legislative text.
In describing the different kinds of support, we have distinguished:

a. support in determining the consistency of legislation, addressing both internal and external consistency aspects,
b. support in determining the socio-economic effects of legislation.

ExpertiSZe supports three methods of consistency checking. The use of the formal representation language KRL and the application of a KRL compiler both help to detect internal inconsistencies. The consistency module helps to find external inconsistencies. The support in determining the socio-economic effects of legislation is given by the simulation module of ExpertiSZe, which may be used to perform knowledge based micro-simulation.

So far our research has shown that there is a strong evidence that the different types of support we have described can indeed help the legislator to improve the quality of new legislation.

Finally, we want to stress that the ExpertiSZe project is still in progress. Our current research focusses on establishing and evaluating the applicability of the system in various domains. Moreover, the problem of implementing the system in the organization of the ministry is investigated. The results of our research are expected to be available at the end of this year [Svensson et al., 1992].

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