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An Artificial Intelligence Approach towards Investigating Corporate Bankruptcy

Ştefan Cristian Gherghina[1]

[1] Department of Finance, Bucharest University of Economic Studies, Bucharest, Romania

Correspondence: Ştefan Cristian Gherghina, Bucharest University of Economic Studies, 6 Romana Square, district 1, Bucharest, 010374, Romania. Tel: 40-213-191-900. E-mail: stefan.gherghina@fin.ase.ro

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Abstract

Corporate bankruptcy analysis is very important for investors, creditors, borrowing companies, as well as governments. The assessment of business failure provides tremendous information for governments, investors, shareholders, and the management based on which financial decisions are taken towards preventing potential losses. Likewise, by researching corporate downfall there could be gathered an early warning signal, together revealing the fields encountering problems. Moreover, nowadays the corporations are facing the senior staff retirement, thus being confronted by the loss of knowledge. Artificial intelligence (AI) seeks the promotion of systems related with human intelligence, comprising reasoning, learning, and problem solving. The most powerful applied field of AI is the area of expert systems (ES). However, the ES are applications that could reproduce the knowledge and experience of a human expert. This paper aims at designing and implementing an ES prototype towards corporate bankruptcy analysis. Therefore, we have considered a couple of production rules based on indebtedness ratios (e.g. General Indebtedness Ratio, Global Financial Autonomy Ratio, Financial Leverage Ratio), as well as solvency ratios (e.g. General Solvency Ratio, Patrimonial Solvency Ratio). For this purpose, Exsys Corvid® was used since it transforms expert knowledge into a structure that enables rendering of guidance and prescription to refine performance, capability, and efficiency, alongside lowering training and costly errors.

Keywords: artificial intelligence, expert system, business failure risk, Exsys Corvid®, production rules, nodes

1. Introduction

The greatest economic recession since the 1930s was widely assigned to poor management in lending, investment, and company debt management. Thus, beyond the downfall of renowned organizations such as WorldCom and Enron, there was ascertained the fact that the world economies have become circumspect of the risks implicated in corporate liability (Aziz & Dar, 2006). Generally, business failure is viewed as a situation that a corporation cannot pay lenders, preferred stock shareholders, and suppliers, a bill is overdraw, or the law makes the corporation go bankruptcy (Dimitras et al., 1996). Withal, a bankruptcy problem emphasizes a case within a group of individuals which have rights over a property, but the property is not huge enough to overspread their joint claims (Albizuri et al., 2010). Unfortunately, corporate bankruptcy engenders massive economic losses to investors and others, at the same time with a considerable social and economical cost to the state (Shuai & Li, 2005). Ooghe and De Prijcker (2008) discovered four different types of failure processes: the failure process of a fruitless start-up, the malfunctioning process of a striving for growth company, the failure process of a dazzled growth company, and the failure process of a listless established company. Therefore, the investigation of bankruptcy provides an early warning signal and reveals the fields emphasizing faintness. Likewise, there are several benefits including cost cutback in credit investigation, better oversight, alongside an augmented debt collection rate (Lee & Choi, 2013).

The most widely well-known univariate study is that of Beaver (1966). Subsequently, Altman (1968) developed the first multivariate study. However, Altman (1968) and Deakin (1974) employed the discriminant analysis to predict corporate bankruptcies, whereas Ohlson (1980) used logit and probit models. At long last, Tam and Kiang (1992) used artificial neural networks towards predicting business failure. In fact, multifarious statistical techniques (such as linear discriminant analysis, LDA; multivariate discriminant analysis, MDA; quadratic discriminant analysis, QDA; multiple regression; logistic regression, logit; probit; factor analysis, FA), neural networks topologies (such as network architectures including multi-layer perception, MLP; radial basis function network, RBFN; probabilistic neural network, PNN; auto-associative neural network, AANN; self-organizing map, SOM; learning vector quantization, LVQ; cascade-correlation neural network, Cascor), as well as other intelligent techniques (such as vector machines, fuzzy logic, isotonic separation) have been applied to settle the bankruptcy prediction problem (Kumar & Ravi, 2007).

Financial decision making is a very complex method since the managers are confronted on a daily basis with a huge amount of information that should be analyzed in order to make the final decision as regards the performance or the viability of a corporation, the granting or denying of a credit request, the construction and management of a portfolio, the choice of an investment, or the construction of a financial marketing plan (Xidonas et al., 2009). The decision process covers several problem solving activities, experience, and heuristics. When a corporation has to make a decision an expert consultancy is employed. Besides, when decisions on significant investments, integration, or advertising strategy should be taken, an expert will be hired in order to provide advice (Grahovac & Devedzic, 2010). In fact, financial experts own knowledge gathered in practice and which cannot be discovered within literature or acquired in any other way, but which is inestimable towards the business success of a corporation or a financial institution (Nedović & Devedžić, 2002).

Artificial intelligence (hereinafter "AI") is a science, as well as a technology, its goal consisting in developing systems which emphasize aspects of intelligent behavior, likewise simulating the human capabilities of thinking and sensing. However, the most important applied field of AI is expert systems. An expert system (hereinafter "ES") incorporates the human expertise into a computer program in order to enable the software to execute tasks normally requiring a human expert (O'Keefe & O'Leary, 1993). As well as, Klein & Methlie (1995) stated that an ES should be viewed as a computer program that represents the knowledge and inference procedures of an expert to enlighten complex problems, giving possible solutions or recommendations. Further, Rada (2008) emphasized that ES could be related to knowledge-based systems or technologies such as the neural networks or genetic algorithms. In fact, these technologies describe the "evolutionary computation" discipline. Besides, an inaccurate system will produce pricey errors or will not execute up to foresights.

The ES technology is based on the sphere knowledge of the problem being analyzed. A problem within a particular field covers the objects, properties, tasks, and events within which a human expert operates, as well as the heuristics that skilled professionals have learned to use in order to execute better (Klein & Methlie, 1995). Unfortunately, the acquisition of the domain knowledge from the experts and the representation of this knowledge in the most suitable form represent the greater hindrance within the process of ES development process. Because the experts are regularly unavailable due to time constraints, gathering knowledge from them depicts a very difficult and time consuming approach. Besides, there is faced a lack of communication between the knowledge engineer and the expert. Therefore, this paper aims at developing an ES prototype in order to assist risk managers towards valuation business failure risk. Moreover, current manuscript exclusively considers the ES technology within the knowledge or the rule-based frame. However, by considering the fact that financial ratios are a key indicator of financial soundness of a business, we will assess a couple of ratios as regards indebtedness and solvency. In order to implement the ES, Exsys Corvid® will be used, being wide-spread towards designing and fielding interactive knowledge automation ES—for the Web (server or client-side), as well as stand-alone systems.

The paper is structured as follows: the fundamentals of ES are provided in Section 2; a review of ES in the economics field is revealed in Section 3; Exsys Corvid® development software is discussed within Section 4; the ES prototype for valuation business failure risk is disclosed in Section 5; concluding remarks and recommendations for further research are proposed in Section 6.

2. Fundamentals of Expert Systems

Nowadays, knowledge management shows a key role in the search for success. The fundamentals, alongside the primordial purpose of an ES consist in its capacity to replicate human logic and reasoning, to set conclusions, and to supply matching explanations as regards these conclusions (Metaxiotis et al., 2006). Moreover, the entire set of issues are of critical importance for the financial decision-making practice, because it implies several judgmental procedures that decision makers (covering managers of companies, managers of credit institutions, individual investors) have to pursue so as to construct the suitable decisions (Metaxiotis, 2005). According to Mannan (2005), the development of an ES suppose crossing the following typical stages: (1) system concept, (2) feasibility study, (3) outline specification, (4) preliminary knowledge acquisition, (5) knowledge representation, (6) tool selection, (7) prototype development, (8) main knowledge acquisition, (9) revised specification, (10) system development, (11) testing and evaluation, and (12) handover. However, the process is an iterative one, with looping back between some of these stages.

Feigenbaum (1982) has defined ES as "an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions". Goodall (1985) stated that "an expert system is a computer system that uses a representation of human expertise in a specialist domain in order to perform functions similar to those normally performed by a human expert in that domain. The system operates by applying an inference mechanism to a body of specialist expertise represented in the form of knowledge". Likewise, Turban and Aronson (1998) noticed that an ES is "a system that uses human knowledge captured in a computer to solve problems that ordinarily require human expertise". Besides, rule-based ES are ES in which the knowledge is represented by production rules. Production rules are IF-THEN condition-action pairs. Moreover, a set of production rules and a computational engine that construes the rules is entitled a production system (Sears & Jacko, 2008). In a system based on production rules, each unit of knowledge is depicted by a single IF-THEN logical statement, whilst an inference engine, assessing the existing data and statements, chooses which statement to execute next (Jenders, 2006). Besides, production systems are one of the major means of enforcing ES. A production system shows three key attributes: the rule base, a working memory, and the inference engine. The rule base comprises the set of rules that embody the expertise of the system. The working memory is provided with the input data, or facts, on the problem to which the rules are to be employed. The inference engine controls the operation of the rules to infer conclusions from these data (Mannan, 2005).

The first ES entitled Dendral (Dendritic Algorithm) was developed in mid 60s by the artificial intelligence researcher Edward Feigenbaum and the geneticist Joshua Lederberg of Stanford University in California, U. S., towards analyzing organic compounds to determine their structure. Subsequently, in early 70s, there was developed MYCIN to help physicians regarding diagnoses infectious diseases. Developed in mid 70s, another famous ES is PROSPECTOR designed for decision-making problems in mineral exploration. In accounting were not available ES until 1977 when McCarthy (1977) developed the earliest tax application of an ES entitled TAXMAN. Further, MACSYMA was a large interactive mathematics ES which could manipulate mathematical expressions symbolically. ONCOCIN and INTERNIST were two other early medical ES towards planning treatment for cancer sufferers, as well as diagnosing multiple medical conditions. XCON was developed to customize a network system to meet the customer's needs. Pathfinder is an ES towards supporting pathologists as regards accurate diagnoses in the domain of lymph-node pathology. Figure 1 exhibits the common organization of an ES.

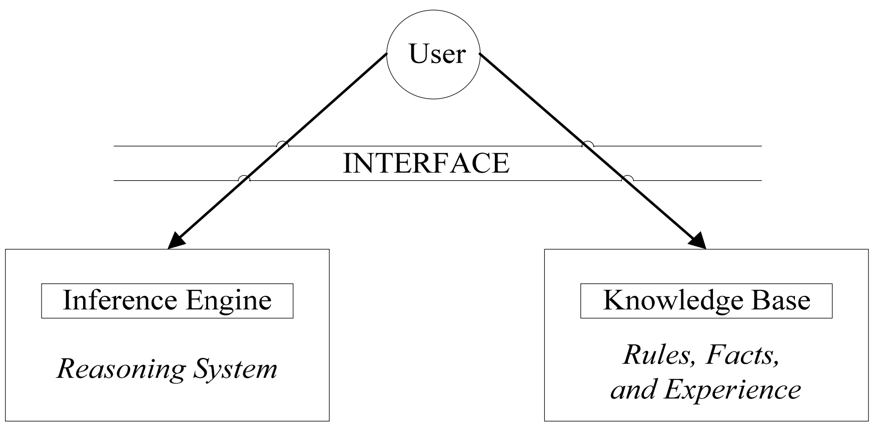

Figure 1. The common organization of an expert system

Source: Romiszowski, A. 1987. *Artificial intelligence and expert systems in education: Progress, promise and problems*. Australian Journal of Educational Technology, *3*(1), 6-24.

Therefore, an ES comprises four main components:

- A natural language required in order to interface and interact with the user;
- A knowledge base containing the rules from which the decisions can be made;

- A database of facts specific to the domain of analysis;
- An inference engine required to solve problems; there are linked the knowledge base rules with the database by means of heuristics or "rules of thumb" logic.

According to Romiszowski (1987), the user initiates a consultation through the interface system. Further, the system questions the user through this same interface with the purpose to gather the essential information upon which a decision is to be made. Moreover, there are two other sub-systems:

- The knowledge base which covers all the domain-specific knowledge that human experts use when solving that type of problems;
- The inference engine, respectively the system that performs the necessary reasoning and uses knowledge from the knowledge base in order to come to a decision regarding the problem placed.

An ES is different than conventional computer programs since there is a clear separation of the rules forming a knowledge base from information about the input data and inference rules to be applied to the knowledge and data bases.

The advantages of ES are discussed below (Gonciarz, 2014):

- Improved disposable—Knowledge is accessible on any appropriate computer hardware. An ES can be considered to be a mass production of expertise;
- Lowered cost—The cost of ensuring expertise per user is deeply mitigated;
- Reduced risk—ES can be used in circumstances that may be assessed unsafe to a human;
- Everlasting—The expertise is long—drawn, contrasting human experts who might retire, quit, or die;
- Manifold expertise—The knowledge of several experts can be made accessible to work concurrently and endlessly on a hobble day or night;
- Enlarged trustworthiness—ES boost confidence that the accurate decision was made by providing a second view to a human expert or break a tie in case of disagreements by many human experts;
- Clarification—ES can obviously clarify in detail the logic that led to a conclusion, whilst a human however may be too exhausted, reluctant, or powerless to do this all the time;
- High-speed reply—According to the software and hardware used, an ES may act in response more rapidly and is more readily on hand than a human expert;
- Steady, unresponsive, and complete response permanently—This may be vital in real time and emergency situations when a human may not run at top efficiency because of pressure or weariness;
- Smart database ES can be used to access a database in an intelligent way;
- Intelligent tutor—ES may proceed as a smart trainer by letting the student run sample programs and explaining the system's reasoning.

Besides, based on Klein & Methlie (1995), Turban et al. (2006), and Zopounidis et al. (1996), ES technology shows several benefits as follows: ES operate and set conclusions by the means of the knowledge and experience of human experts; ES hammer out conclusion more rapidly than humans, particularly in complex problem areas where an outsized volume of information and data should be processed and investigated; ES ensure the manipulation of partial information and vagueness; the estimations of ES are consistent; a novice can study the procedure, the heuristics, and the problem-solving methodology that an expert would use to solve a particular problem.

The disadvantages of ES are discussed below (Gonciarz, 2014):

- Answers may not constantly be truthful—Experts regularly make mistakes, so it can be anticipated that ES will also make mistakes. Unfortunately, such errors could be relatively expensive at times;
- Knowledge restricted to the domain of expertise—ES always try to infer a solution, despite of whether or not the problem at hand is within the system's area of knowledge. A human expert, in contrast, will know the limits of their abilities and knowledge, and as a result they will not struggle to solve problems outside of their expertise;
- Lack of common sense knowledge can be thorny to represent in ES;
- ES can provide an excellent approach for solving a huge class of problems, but each application must be selected with awareness so this technology is properly applied.

The differences between conventional computer programs and ES (Durkin, 1990) are provided in

Table 1. However, the basic difference is depicted by the fact that conventional programs process data, whereas ES process knowledge.

Table 1. Conventional programs versus expert systems

Conventional Programs	Expert Systems
Numeric	Symbolic
Algorithmic	Heuristic
Precise information	Uncertain information
Command interface	Natural dialogue with explanations
Final solution given	Recommendation with explanation
Optimal solution	Acceptable solution

Source: Durkin, J. 1990. *Research review: Application of expert systems in the sciences*. Ohio Journal of Science, *90*(5), 171-179.

A comparison between a human expert and an ES is revealed in

Table 2. Durkin (1990) stated that one can establish several general reasons towards employing an ES, respectively replacement of human expert, assistant to human expert, or transfer of expertise to novice.

Table 2. Comparison between a human expert and an expert system

Factor	Human Expert	Expert System
Time availability	Workday	Always
Geographic	Local	Anywhere
Availability	Yes	No
Perishable	No	Yes
Consistent results	High	Affordable
Cost	Variable	Consistent
Productivity	Human Expert	Expert System

Source: Durkin, J. 1990. *Research review: Application of expert systems in the sciences*. Ohio Journal of Science, *90*(5), 171-179.

3. A Review of Expert Systems in the Economics Field

According to Nedović & Devedžić (2002), there are several groups of ES for finance according to the problem they treat: FINEVA (from the field of financial analysis), PORT-MAN (banking management), INVEX (investment advisory), FAME (financial marketing), and DEVEX (an ES for currency exchange advising in international business transactions). Koster and Raafat (1990) depicted a prototype ES towards auditing workers' compensation insurance premium. Srinivasan and Ruparel (1990) described an expert support system for credit granting (CGX) in nonfinancial firms. Biack and Grudnitski (1991) pointed out a tax ES (TaXpert) to establish constructive ownership of corporate stock under the rules of 60 sections of the Internal Revenue Code. Bohanec et al. (1995) showed a computer-based ES for the assessment of research and development projects. Kailay and Jarratt (1995) developed a qualitative based prototype ES designed for small to medium-sized commercial organizations (RAMeX) aiming to help management towards security decisions and planning. Grahovac and Devedzic (2010) developed a cost management ES (COMEX).

Lee and Jo (1999) designed an ES covering patterns and rules which could predict future stock price movements. Zargham and Mogharreban (2005) built an ES entitled PORSEL (PORtfolio SELection system), which used a small set of rules to select stocks, consisting of three components: the Information Center, the Fuzzy Stock Selector, and the Portfolio Constructor. There was noticed that the portfolios constructed by PORSEL consistently outperform the S&P 500 Index. Xidonas et al. (2009) discussed an ES methodology as regards supporting decisions related to the selection of equities, on the basis of financial analysis. By using the Dempster-Shafer theory, Dymova et al. (2010) illustrated another way to develop stock trading ES. Fasanghari and Montazer (2010) suggested a fuzzy ES in order to evaluate the stocks of the Tehran Stock Exchange, subsequently making the portfolio and recommending it to the target customers based on their preferences and stocks pay off. Lee and Lee (2012) discussed a causal knowledge-based ES for planning an Internet-based stock trading system (CAKES-IST). Yunusoglu and Selim (2013) developed a fuzzy rule based ES to assist portfolio managers in their middle term investment decisions.

Rao et al. (2005) proposed a knowledge-based prototype system for productivity analysis (PET, productivity evaluation technology). By using artificial neural networks, Kengpol and Wangananon (2006) developed an ES to appraise customer satisfaction on fragrance notes. Lee and Kwon (2008) proposed an intelligent negotiation support system (CAKES-NEGO, CAusal Knowledge-driven Expert System), by employing causal knowledge as well as inference mechanism supported by fuzzy cognitive map. Bobillo et al. (2009) suggested a semantic fuzzy ES which applies a generic framework for the balanced scorecard. Arias-Aranda et al. (2010) created a fuzzy ES tool (ESROM) in order to help managers to imitate strategic environments to gather useful information regarding the levels of strategy, flexibility, and performance compulsory in the operations management area. Oh et al. (2012) suggested an ES for portfolio analysis aiming to help decision-making for new product development project portfolio management. Chung (2014) developed and evaluated an intelligent system (BizPro) for extracting and categorizing the business intelligence factors from news articles.

4. Exsys Corvid® Development Software

An expert system tool, also known as shell depicts a software development environment covering the fundamentals components of ES. Exsys Corvid® was released in 2001 by Exsys Inc., being a very influential environment towards developing knowledge automation systems which allows the logical rules and procedural steps used to make a decision to be transformed to a "rule" representation that can be delivered on-line. An Exsys Corvid® knowledge automation system comprises the logic of the decision-making process, as well as the end user interface. Knowledge Automation ES with Exsys Corvid® software and services were developed worldwide within multifarious fields such as: Diagnostics—Predictive Maintenance—Repair; Government—Regulatory Compliance; Customer Support—Help Desks; Environmental; Implementing Best Practices; Electronics—Aerospace—Telecommunications; Energy—Utilities—Oil & Gas; Manufacturing—Quality Control; Capturing Corporate Knowledge; Financial Services—Legal; Engineering—Design—Research; Advanced Business Rules; Military—Security; Chemical—Food; Agriculture—Earth Sciences; Construction—Transportation; Medical—Healthcare—Safety; Human Resources—Customer Relationship Management; Sales—Marketing; Smart Questionnaires—Training—Education.

ES development with Exsys Corvid® has the following main parts: entirely capturing the decision-making logic and process of the domain expert; wrapping the system in a user interface with the desired look-and-feel for online deployment; integrating with other IT resources. The main advantage is that Exsys Corvid® provides non-programmers a path towards developing interactive Web applications that capture the logic and processes used to solve problems, delivering it online, in stand-alone applications, and embedded in other technologies. Exsys Corvid® provides the following main options towards system delivery: running as a Java Applet in a web page; running as a Java Servlet using HTML; running as a Java Servlet using Adobe Flash; running standalone (off-line) as a Java executable; embedded under another program that provides the end user interface.

The logic in Exsys Corvid® is emphasized by employing the specific variables. In fact, the variables are the building blocks that Exsys Corvid® employs in order to create the rules and describe the logic. When the system is run, the variables utilized in the IF part of rules will require to be assigned a value coming by directly asking the system user to provide a value, being derived from other rules, or from other sources such as a database.

Exsys Corvid® System Requirements are provided below:

- Microsoft Windows 8, 7, Vista, 2000, 2003, XP;
- Microsoft Internet Explorer ver. 5 or higher;
- 150 MB Free Disk Space;
- Minimum Screen Resolution: 1024 x 768 with standard fonts or 1152 x 864 with large fonts.

5. Expert System Prototype for Valuation Business Failure Risk

Hereinafter is discussed an ES prototype for valuation business failure risk, in this sense, Exsys Corvid® shell being used. For this purpose, a couple of production rules are designed based on indebtedness ratios (e.g. General Indebtedness Ratio, Global Financial Autonomy Ratio, Financial Leverage Ratio), as well as solvency ratios (e.g. General Solvency Ratio, Patrimonial Solvency Ratio). General Indebtedness Ratio emphasizes the percentage of total assets that were financed by creditors, liabilities, debt. Global Financial Autonomy Ratio shows the percentage of company financing that comes from creditors and investors. Financial Leverage Ratio depicts the proportion of equity and debt the company is using to finance its assets. General Solvency Ratio shows the relationship of the total assets of the corporation to the portion owned by shareholders. Patrimonial Solvency Ratio reveals how much shareholders would receive in the event of a company-wide liquidation.

The formula for each selected financial ratio is provided below:

- General Indebtedness Ratio = Total Debt/Total Assets;
- Global Financial Autonomy Ratio = Total Debt/Shareholders' Equity;
- Financial Leverage Ratio = Bank Loans/Shareholders' Equity;
- General Solvency Ratio = Total Assets/Shareholders' Equity;
- Patrimonial Solvency Ratio = Shareholders' Equity/Total Assets.

However, by using the ES, the financial risk manager should not compute the ratios previously mentioned since the ES performs the entire task that would otherwise be fulfilled by a human expert. Hence, the financial risk manager should know only the values related to Total Assets, Shareholders' Equity, Total Debt, and Bank Loans, the source of data being the Balance Sheet. Accordingly, Exsys Corvid® Expert System Development Tool is employed in order to implement the ES. Moreover, there was chosen the default option, respectively running the system with the Corvid Applet Runtime. The acquired knowledge is represented through production rules. Rule based representation is one of the widest known and implemented forms for knowledge representation in the development of ES. Production rules have a very simple syntax form, they are easily understandable, while their implementation provides a great degree of flexibility to the ES as they are easy to modify and update. With a rule base, knowledge can be developed by either data-driven or goal-driven search. Data-driven or forward chaining suppose that one has a supply of facts and persistently employs legal moves or rules to produce new facts to get hopefully to the goal. Goal-driven or backward chaining implies that one repeatedly considers the possible final rules that produce the goal and from these creates successive sub goals

Exsys Corvid® decision-making logic is described and constructed using "nodes". Exsys Corvid® uses IF-THEN rules of thumb ("heuristics"), being individual steps or factors which provide the global decision, based on variables. Hereupon, a node can generally be thought of as a statement in the IF, or THEN part of a rule. The rules have a Left-Hand Side (LHS) entitled antecedent, premise, condition, or situation, as well as a Right-Hand Side (RHS) named consequent, conclusion, action, or response. The proposition on the LHS may be a compound one with a number of propositions ANDed together. However, a proper set of rules or productions, should be used to form the basis of a production system (Mannan, 2005).

The employed variables are showed in Figure 2.

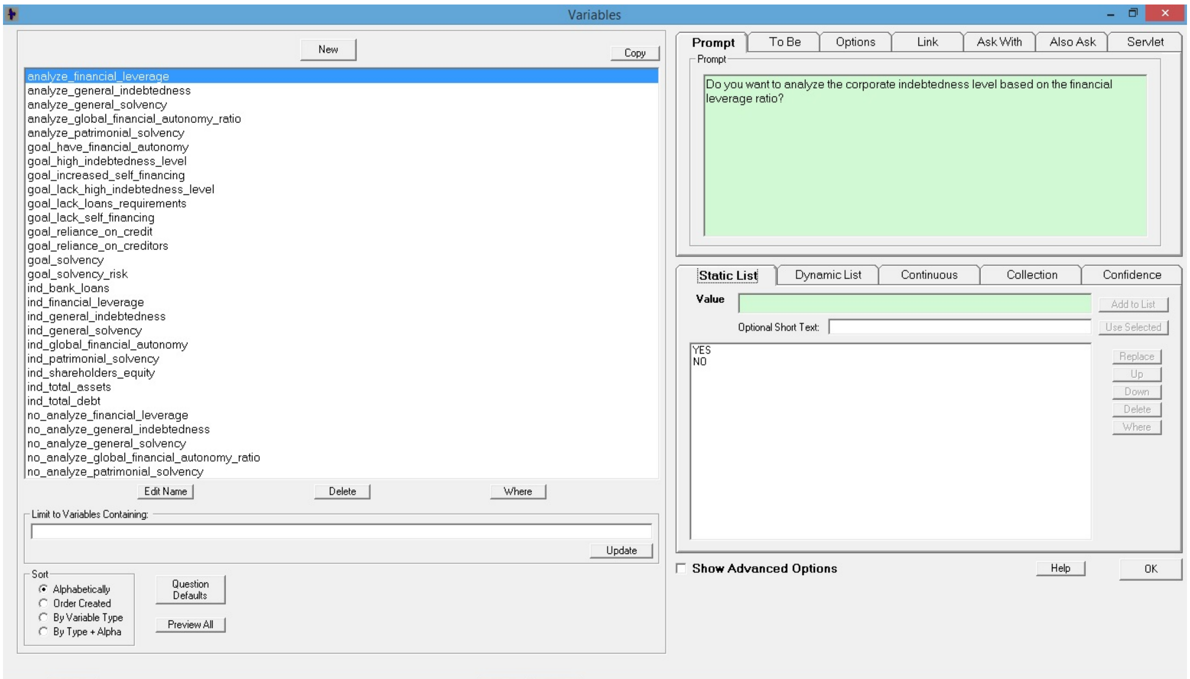

Figure 2. Exsys Corvid® variables window

Source: Authors' processing.

Besides, Exsys Corvid® has a unique way to define, organize, and structure rules into logically related modules. Thus, a Logic Block (hereinafter "LB") comprises one or more structured logic diagrams.

The logic may be a simple structure corresponding more to a single rule or a complex branching tree covering all possible input cases. The rules from the LB integrate a group of related heuristics and provide an explanation how to resolve each potential decision point in a system. The rules are added to the knowledge-base by experts using text or graphical editors that are integral to the system shell. The LB and the related rules are disclosed in Appendix A.

As well as, Command Blocks (hereinafter "CB") control the procedural flow of the system. The CB of current ES is provided in Figure 3. The LB provide the rules of how to make a decision, whilst the CB tell the system what to do and how the rules should be used.

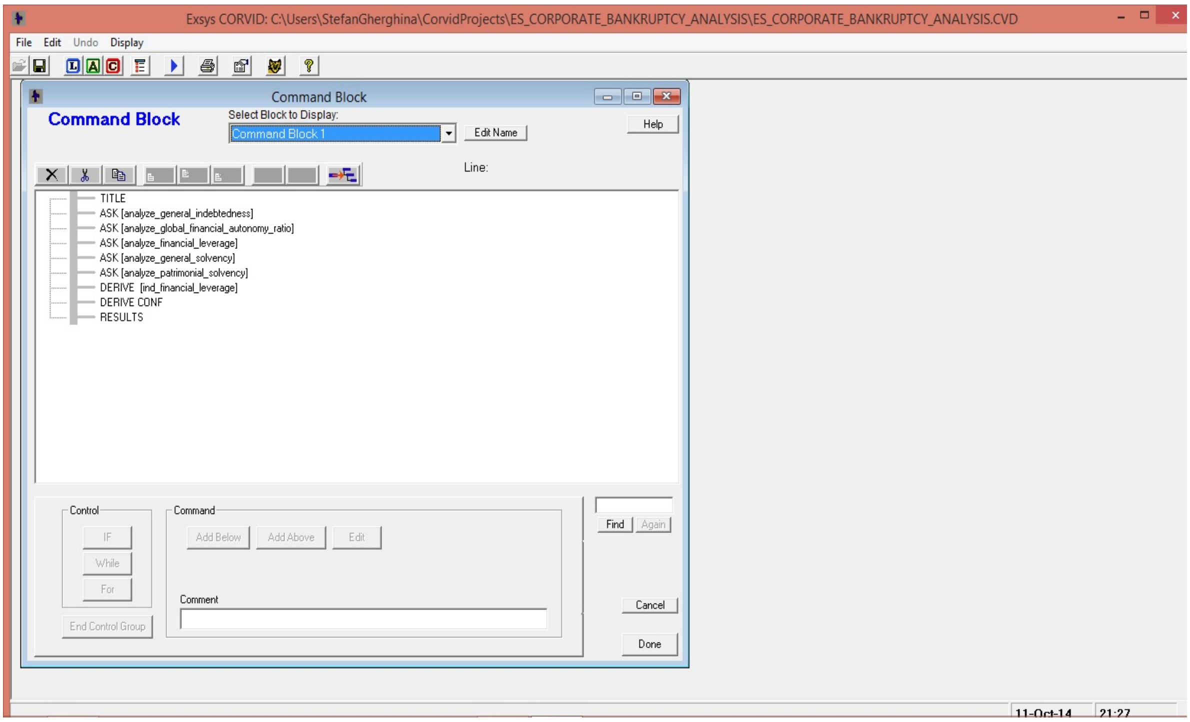

Figure 3. Exsys Corvid® Command Block window

Source: Authors' processing.

In order to test the suggested ES we will consider the following values (USD in Million): Total Assets = 172,384; Shareholders' Equity = 89,784; Total Debt = 82,600; Bank Loans = 20,645, corresponding to Microsoft Corp. (MSFT), at 2014-06.

The user is asked gradually if he agrees to analyze the corporate indebtedness level based on the General Indebtedness Ratio, Global Financial Autonomy Ratio, and/or Financial Leverage ratio, and then if he admit the investigation of solvency based on the General Solvency Ratio and/or Patrimonial Solvency Ratio (see Appendix B). Subsequently, the user is requested to enter the values related to Total Assets, Shareholders' Equity, Total Debt, and Bank Loans (see

Appendix C). Finally, the ES provides a brief report, but vital, in order to assess the business failure risk (see Appendix D). In fact, based on a couple of financial ratios, a financial manager could establish if there are corporate shortcomings. However, even if there were not employed several corporate measures, the output gathered is significant since the selected ratios are fundamental within financial management.

6. Concluding Remarks and Further Research

Nowadays, business decisions cannot wait for an expert advisor. However, ES are essential for people in order to solve complex decision-making problems without learning the underlying logic or requiring specialized training. Moreover, by means of Web any individual could access the ES, as well as employees that are online can also run the same systems stand-alone. By using Exsys Corvid® Expert System Development Tool, ES could be developed quickly, even if the person in not a programmer. Therefore, by using Exsys Corvid®, an ES prototype in order to assist risk managers towards valuation business failure risk was proposed. In fact, by selecting a couple of data out of the Balance Sheet, such as Total Assets, Shareholders' Equity, Total Debt, and Bank Loans, the ES suggested within current paper provides a brief report, but vital, in order to assess the business failure risk. Besides, by using the ES, the financial risk manager should not compute several ratios as regards indebtedness (e.g. General Indebtedness Ratio, Global Financial Autonomy Ratio, Financial Leverage Ratio) or solvency (e.g. General Solvency Ratio, Patrimonial Solvency Ratio) since the ES performs the entire task that would otherwise be fulfilled by a human expert. Hence, ES are an appreciable tool for corporations. However, there is suggested for the companies to keep in mind that humans should make the final decision instead of computers. Accordingly, humans still own the comprehension and perception, whereas until now the computer does not possess such features. The limitations of current manuscript are depicted by the reduced number of financial ratios which were selected. As such, as future research avenues, several ratios with the purpose of valuation business failure risk should be employed.

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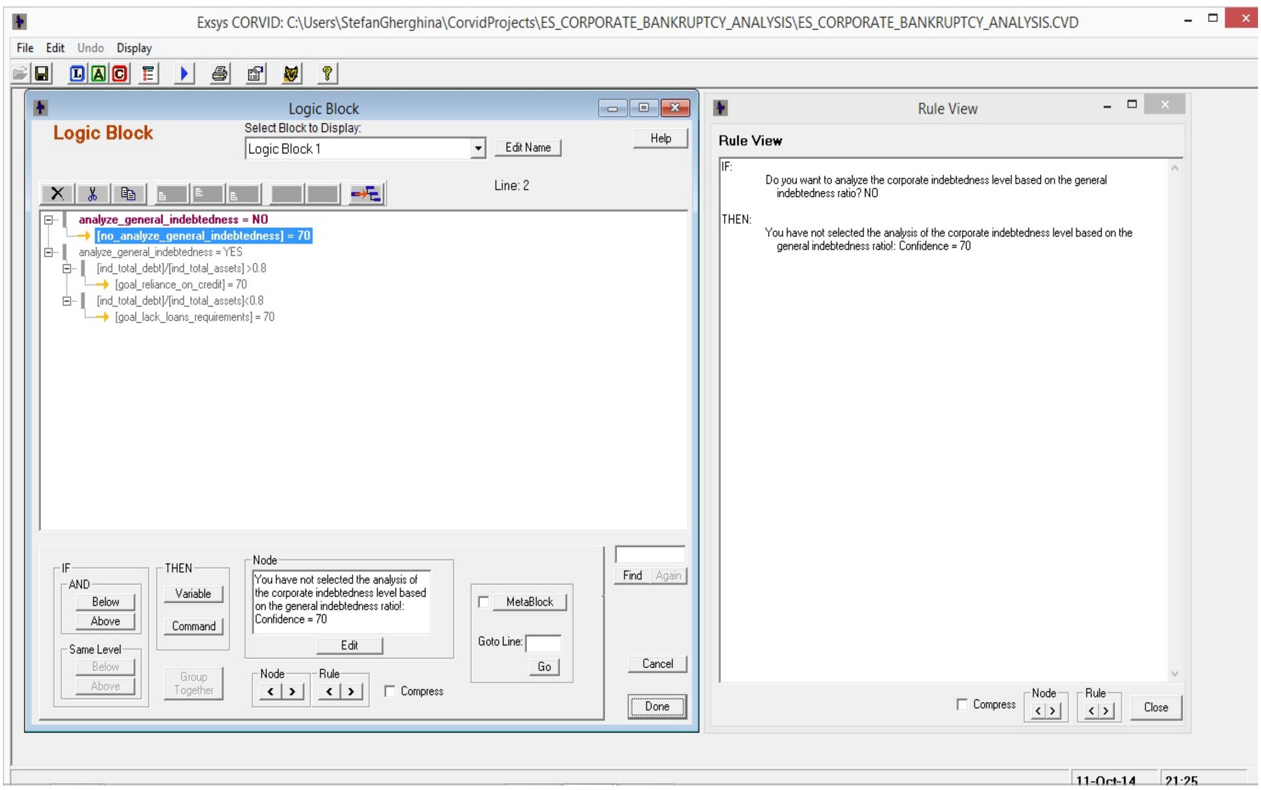
Appendix A

The rules in the Logic Blocks

LB 1



Source: Authors' processing.

The LB displayed above is equivalent to the following rules:

IF:

Do you want to analyze the corporate indebtedness level based on the general indebtedness ratio? NO

THEN:

You have not selected the analysis of the corporate indebtedness level based on the general indebtedness ratio!: Confidence = 70

IF:

Do you want to analyze the corporate indebtedness level based on the general indebtedness ratio? YES

AND: [ind_total_debt]/[ind_total_assets] >0.8

THEN:

The company is dependent on loans. The current financial state is ALARMING!!!: Confidence = 70

IF:

Do you want to analyze the corporate indebtedness level based on the general indebtedness ratio? YES

AND: [ind_total_debt]/[ind_total_assets]<0.8

THEN:

The company does not require bank loans: Confidence = 70

LB 2

IF:

Do you want to analyze the corporate indebtedness level based on the global financial autonomy ratio? NO

THEN:

You have not selected the analysis of the corporate indebtedness level based on the global financial autonomy ratio!: Confidence = 70

IF:

Do you want to analyze the corporate indebtedness level based on the global financial autonomy ratio? YES

AND: [ind_total_debt]/[ind_shareholders_equity]>0.5

THEN:

The company depends heavily on lenders and the related risk is higher: Confidence = 70

IF:

Do you want to analyze the corporate indebtedness level based on the global financial autonomy ratio? YES

AND: [ind_total_debt]/[ind_shareholders_equity]<0.5

THEN:

The company records global financial autonomy: Confidence = 70

LB 3

IF:

Do you want to analyze the corporate indebtedness level based on the financial leverage ratio? NO

THEN:

You have not selected the analysis of the corporate indebtedness level based on the financial leverage ratio!: Confidence = 70

IF:

Do you want to analyze the corporate indebtedness level based on the financial leverage ratio? YES

AND: [ind_bank_loans]/[ind_shareholders_equity]>2.33

THEN:

The company records a very high level of indebtedness: Confidence = 70

IF:

Do you want to analyze the corporate indebtedness level based on the financial leverage ratio? YES

AND: [ind_bank_loans]/[ind_shareholders_equity]<2.33

THEN:

The company does not record a very high level of indebtedness: Confidence = 70

LB 4

IF:

Do you want to analyze the corporate solvency based on the general solvency ratio? NO

THEN:

You have not selected the analysis of the corporate solvency based on the general solvency ratio!: Confidence = 70

IF:

Do you want to analyze the corporate solvency based on the general solvency ratio? YES

AND: [ind_total_assets]/[ind_shareholders_equity]>1.5

THEN:

The company shows the ability to return the loans: Confidence = 70

IF:

Do you want to analyze the corporate solvency based on the general solvency ratio? YES

AND: [ind_total_assets]/[ind_shareholders_equity]<1.5

THEN:

The company records solvency risk: Confidence = 70

LB 5

IF:

Do you want to analyze the corporate solvency based on the patrimonial solvency ratio? NO

THEN:

You have not selected the analysis of the corporate solvency based on the patrimonial solvency ratio!: Confidence = 70

IF:

Do you want to analyze the corporate solvency based on the patrimonial solvency ratio? YES

AND: [ind_shareholders_equity]/[ind_total_assets]>0.3

THEN:

The company records an increased self-financing ability: Confidence = 70

IF:

Do you want to analyze the corporate solvency based on the patrimonial solvency ratio? YES

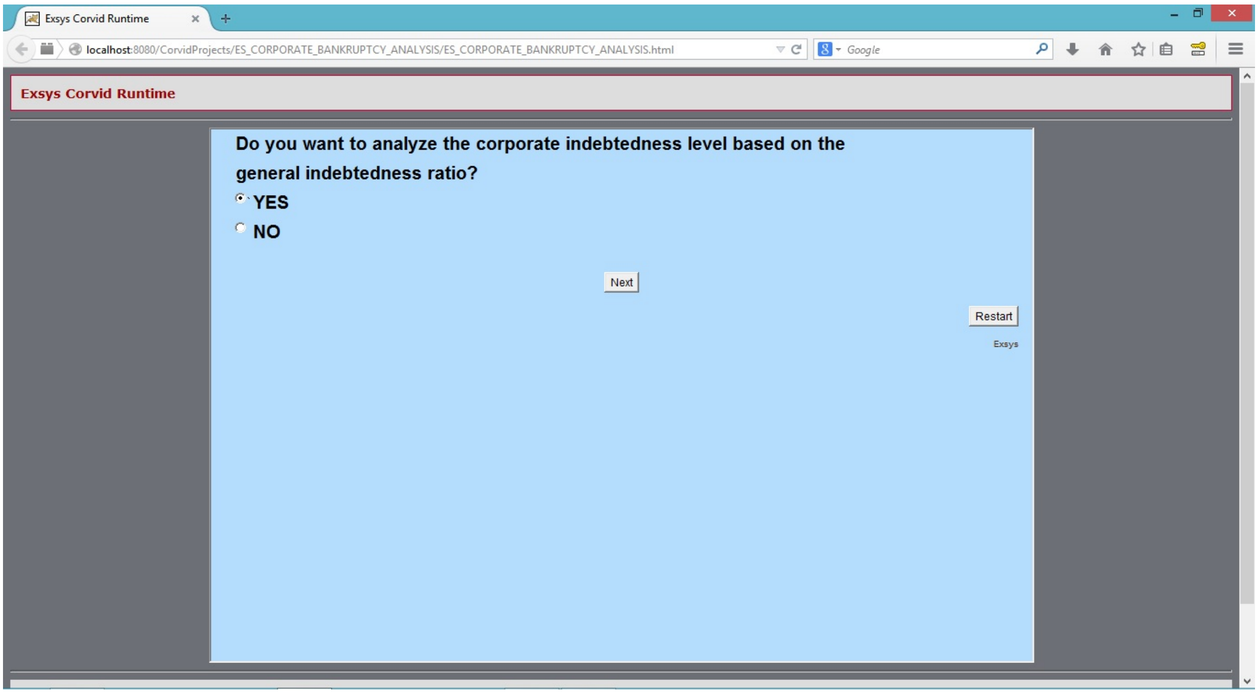
AND: [ind_shareholders_equity]/[ind_total_assets]<0.3

THEN:

The company does not record self-financing ability: Confidence = 70

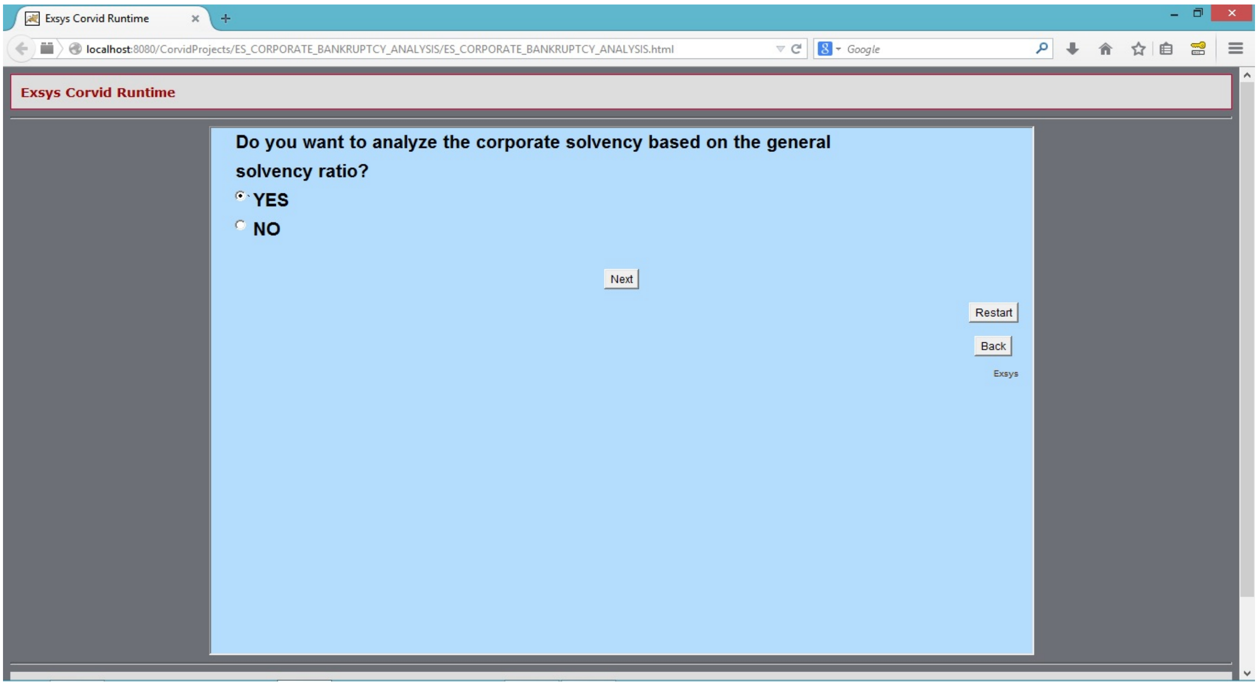
Appendix B

The questions regarding the investigation of the corporate indebtedness and solvency



Asking the user towards the investigation of the corporate indebtedness level based on the general indebtedness ratio

Source: Authors' processing.

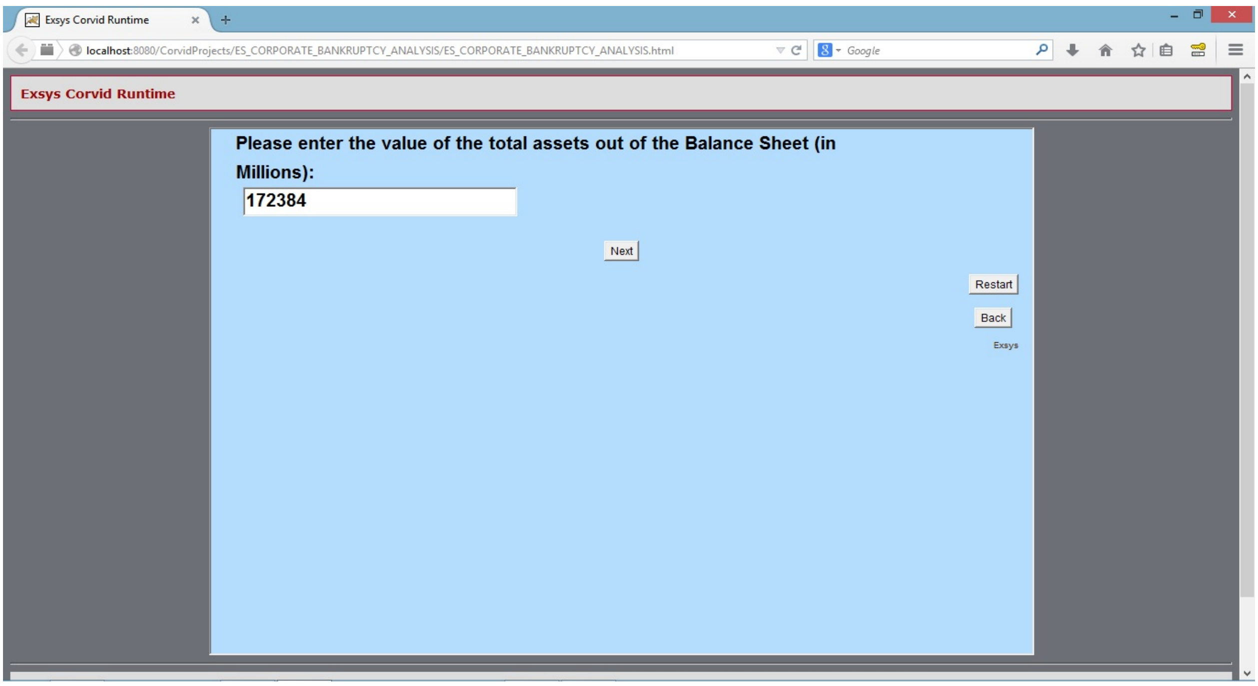


Asking the user towards the investigation of the solvency based on the general solvency ratio

Source: Authors' processing.

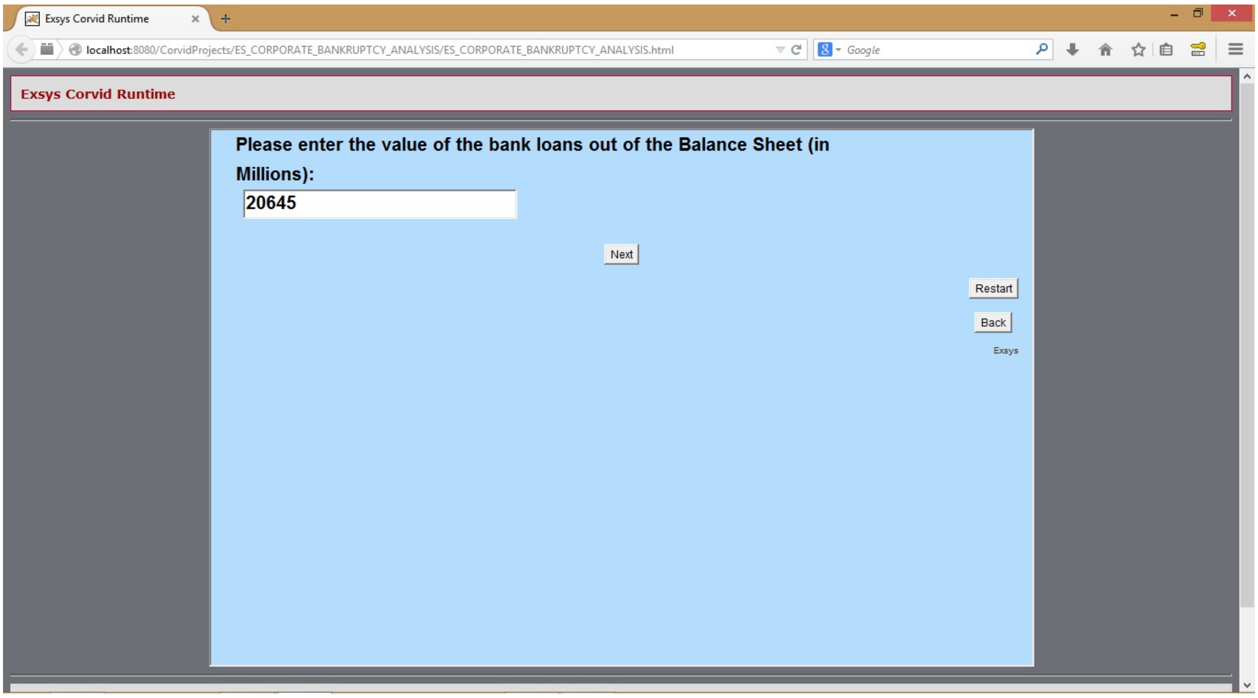
Appendix C

The windows within the user is requested to enter the values of data out of the Balance Sheet



Asking the user to enter the value of the total assets out of the Balance Sheet

Source: Authors' processing.

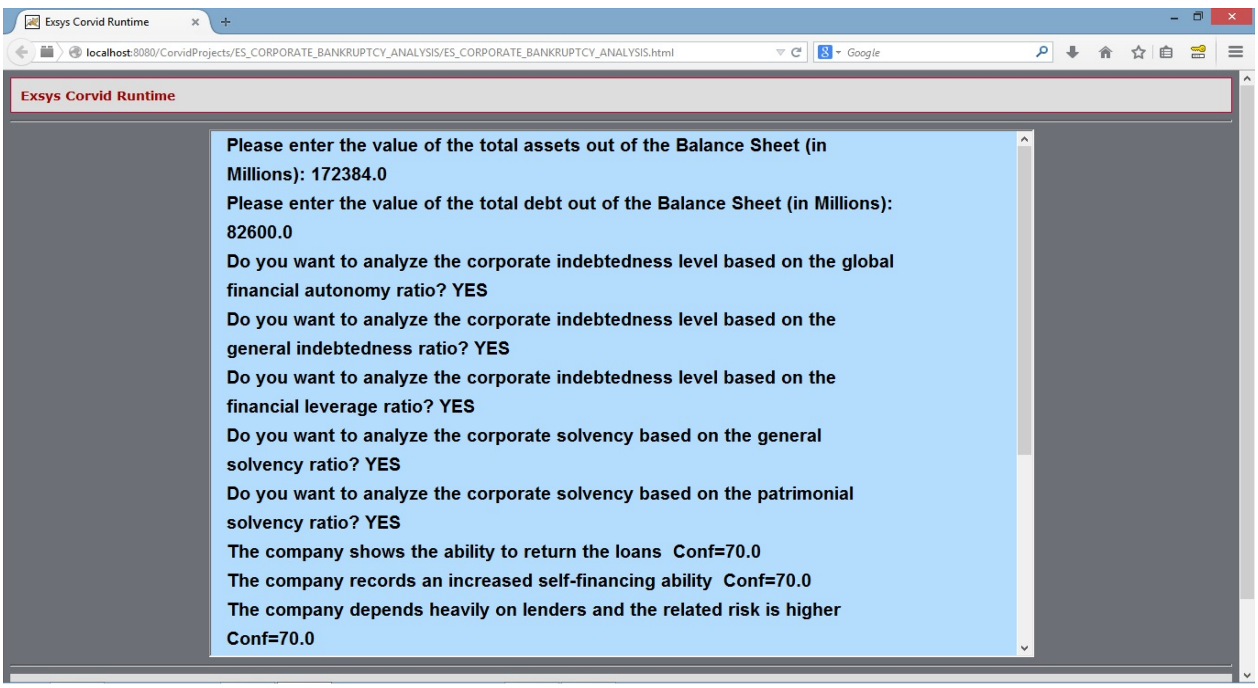


Asking the user to enter the value of the bank loans out of the Balance Sheet

Source: Authors' processing.

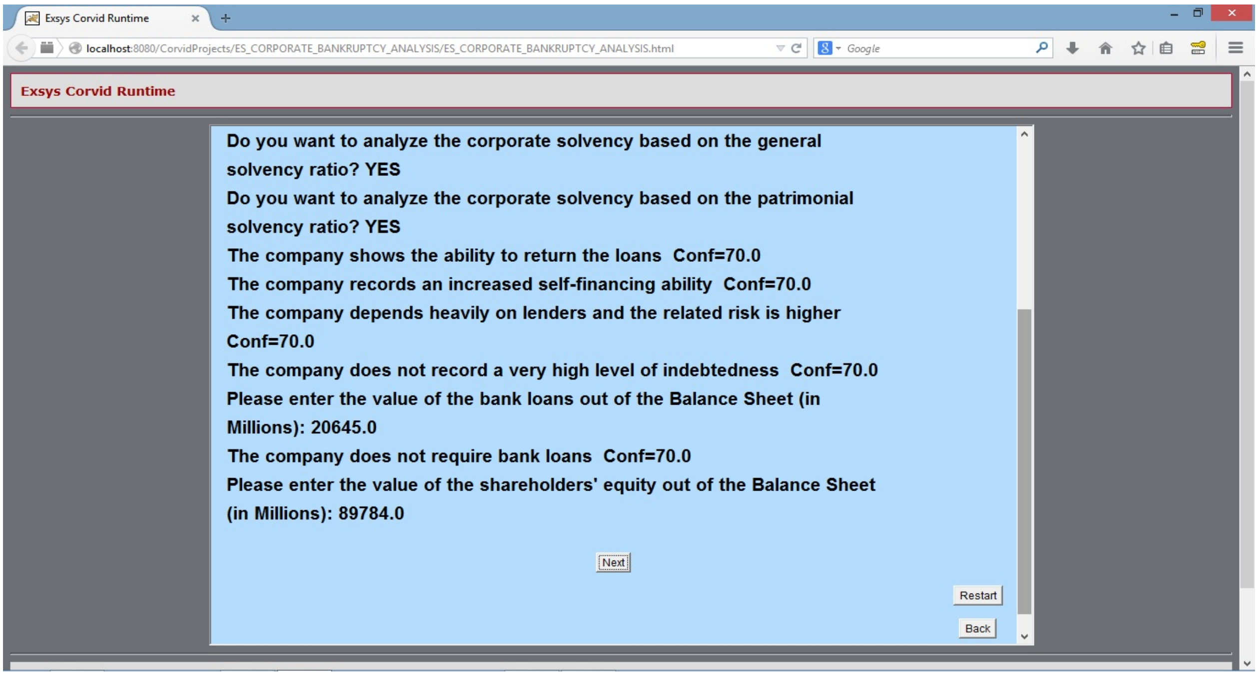
Appendix D

The report provided by the expert system prototype towards corporate bankruptcy analysis



ES message towards corporate bankruptcy analysis

Source: Authors' processing.



ES message towards corporate bankruptcy analysis

Source: Authors' processing.

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