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An evaluation of the use of expert systems in economics

Introduction

An expert system is a computer program which combines the knowledge about a certain domain of expertise. These programs support humans during their decision-making process in this domain[2].Generally, expert systems are considered to be a discipline of artificial intelligence[3]. These systems use knowledge of human experts and imitate their thinking, skills and intuition[4]. They have successfully been used in many different scientific disciplines, such as biology, medicine, business studies, and finance[5]. It is remarkable that apart from some attempts, expert system shave not often been applied in economics and econometrics. Consequently, the aim of this paper is to examine the following hypothesis: *Expert systems can extend traditional economic modelling, and are useful to be applied in economics*.

In order to qualitatively examine this hypothesis, a SWOT analysis will be used. In contrast, it is neither the aim of this paper to give an exhaustive literature overview on expert systems, nor to describe how different expert systems work in details.

The paper is organized as follows. The first section starts with an intuitive example. This section also outlines the typical structure of expert systems and introduces some concrete examples. After this, it will be outlined why economics could benefit from applying expert systems more often. The above hypothesis will be assessed in section three. At the end, all arguments are recapped, and a concrete benefitting field for applying expert system in economics is suggested.

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2 A. Bahrammirzaee, *A comparative survey of artificial intelligence applications in finance*, "Neural Computing & Applications" 2010, vol. 8, p. 1173.

3 P. Mertens, *Grundzüge der Wirtschaftsinformatik,* 5 ed., Springer, Berlin 1998, p. 53.

4 F. Nelson Ford, *Decision support systems and expert systems. A comparison*, "Information & Management" 1985, vol. 1, p. 23.

5 A good overview can be obtained from S.-H. Liao, *Expert system methodologies and applications – a decade review from 1995 to 2004*, "Expert Systems with Applications" 2005, vol. 1, p. 93–103.

1. Short historic overview and examples of expert systems

1.1. Small motivating example

There are many potential causes of headache. For now, let us restrict to three possible causes, namely the person caught a cold, the person suffers from high blood pressure, or that person has a tumour. Let us assume only the following variables of Tab. 1 are applied:

Table 1. Potential variables

Variable	Characteristic values
Cold	{yes, no}
Blood Pressure	{high, medium, low}
Tumour	{yes, no}
Headache	{yes, no}
Body temperature	{high, normal, low}
Blocked nose	{yes, no}

Source: Own elaboration.

From a medical point of view, it is certainly possible to derive how likely a person would be suffering from a headache if he/shecaught a cold. Here, the headache is called the symptom, whereas the fact that someone has a cold is called the cause. Expressed in probabilistic terms, we might be able to extract from a possible medical study the following relationship:

$$P(\text{Headache} = \text{yes} \mid \text{Cold} = \text{yes}) = 0.8 \quad (1)$$

In fact, equation (1) is a conditional probability. It expresses when the patient has a cold, with a probability of 80%, he or she will suffer from a headache. Rules like stated in (1), can be calculated when having a sufficient amount of patients suffering from a cold. However, from a practical point of view, it is more interesting to invert equation (1). Since the symptoms are observable, one wants to infer, if that person has caught a cold or a serious sickness. Speaking in probabilistic terms, we are rather interested in the following equation:

$$P(\text{Cold} = \text{yes} \mid \text{Headache} = \text{yes}) = x \text{ with } x \in [0,1] \quad (2)$$

The situation can be transferred to economics. Economist can observe certain symptoms = variables like GDP, interest rates, inflation etc. However it is more interesting for economists to explain the causes = variables which determined the symptoms to take on a particular level.

In medicine expert systems were of help. The expert system is a computer program that comprises of knowledge from many physicians, medical literature,

as well as statistical knowledge. This approach motivates applying expert systems in economics more often.

1.2. Typical structure of expert systems

A common concept to visualize expert systems is shown in Figure 1.

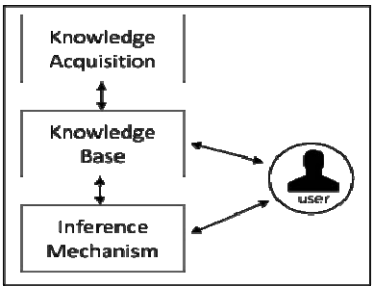

Figure 1. Concept of expert systems

Source: F. Nelson Ford, *Decision support systems and expert systems. A comparison*, "Information & Management" 1985, vol. 1, p. 23.

Before an expert system can be used, knowledge from different sources in a particular domain has to be acquired. It can come from human experts, from statistical or data mining routines, or be extracted from academic texts. The knowledge base is considered the core of this concept, since it stores the acquired knowledge as a set of rules. A single rule from a knowledge base from an economic expert system could be of the following form:

> If the stock of money circulating in an economy is increased,
> it will cause inflation to increase, with a probability of 70%[6].

All rules together form the knowledge base. However, knowledge can be represented in a base, using a variety of techniques e.g., semantic nets, frames, predicate logic, probabilistic rules. The most common concept is the "if–then" rules[7]. The last component, the inference procedure, complements the expert system. There exist different types of inference engines. However, they all aim to answers user inquires by engaging with the knowledge base.

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[6] This rule could also be expressed by using the notation of conditional probabilities as we did before: P(Inflation = increasing | Money stock = increasing) = 0.7.

[7] A. Bahrammirzaee, *A comparative…*, p. 1173.

1.3. Examples of expert system

The abbreviation LEXMED stands for learning expert system for medical diagnosis. It is based on the principle of maximum entropy[8]. The computer program aims to aid diagnosing acute abdominal pain, especially under the condition of a suspected appendicitis. Based on 15.000 patient records,400 probabilistic rules were derived and complemented by 100 probabilistic rules from human medical experts. The physician can use LEXMED[9]in parallel while diagnosing a patient byentering13 patient's information like sex, age belly pains etc. The system afterwards provides its view whether the patient needs a surgery to have the appendicitis removed or not. Important, this system is based on probabilities, and therefore, it has only advisory character.

The applications of expert systems in non-economic scenarios apart from medicine are manifold. It would be impossible to list them all. The interested reader is referred to Liao[10], who gives a concluding overview on where expert systems have been applied.

The business model of financial institutions essentially depends on having precise information on how the economy is changing. Consequently, banks often carry out economic research, including expert systems. Bryant presents an expert system designed for a bank to assess agricultural loan evaluation. This system is able to incorporate qualitative as well as quantitative factors. Quantitative factors are the borrower's financial position, the current markets, and the economic conditions, where as qualitative factors describe the character of the borrower[11]. Bryant considers qualitative factors to be especially crucial for successfully predicting a borrower's creditworthiness[12]. In order to apply this expert system, the user is asked to provide information of 14 quantitative variables e.g. gross ratio, income etc.[13]. Additionally, the system uses eleven qualitative factors, such as the farmer's honesty and integrity etc. A survey by Bahrammirzaee came to the conclusion that this expert system performed better than traditional approaches in estimating the credit worthiness[14].

Not many applications of expert systems in economics can be found. Bahrammirzaee evaluates 27 expert systems in business applications such as portfolio

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[8] M. Schramm, W. Ertel, *Reasoning with probabilities and maximum entropy: The system PIT and its application in LEXMED,* "Operations Research Proceedings, Selected Papers of the Symposium on Operations Research (SOR'99)" 2000, p. 278.

[9] A demo version of this expert system is available online: www.lexmed.de [access: 9/2/2017].

[10] S.-H. Liao, *Expert system…*, p. 93–103.

[11] K. Bryant, *An agricultural loan evaluation expert system*, "Expert Systems with Applications" 2001, vol. 2, p. 75.

[12] Ibidem, p. 77.

[13] Ibidem.

[14] A. Bahrammirzaee, *A comparative…*, p.1176.

management, credit evaluation, and financial prediction. For example, Bahrammirzaee evaluates expert systems on forecasting mutual funds and corporate financial rating in his financial prediction section. Consequently, the applications in this area seem to be very close to econometrical application, e. g., predicting the inflation rates. Bahrammirzaee comes to the ultimate conclusion that all twelve expert systems performed better than the traditional methods[15].

Expert system can also be combined with empirical methods. For example, Petropoulos et al proposed a variation of the theta model[16] with an expert system. For this purpose, the theta model was used on daily Greece's mutual funds time series data, and this model was afterwards embedded into an easy-to-handle expert forecasting system[17].

2. Benefits from applying expert systems in economics and econometrics

Finding the best model for an economic relationship based on data is often associated with a trial and error process. Usually, a model is built and afterwards its fit is evaluated by applying statistical tests. If these tests do not assure a certain level of confidence, the model will be rejected and a second model is built, engaging the same pool of data. Expert systems follow a different philosophy. If a given expert system (= model) does not produce sufficient results, the model is not rejected. Its knowledge base is rather, extended, and additional knowledge (= data) is integrated. This idea follows the belief that successful humans do not process knowledge differently when compared to other humans. However, the successful people possess different sources of knowledge[18].

Expert systems can provide a meaningful addition to traditional methods in economics. E.g. economists could use an inflation expert system to get a computer-aided second opinion, if next period's inflation is going to increase, be constant, or decline. This opinion is not arbitrary. It is based on valid sources, because ideally, many human inflation experts have helped to build the knowledge base of the expert system.

The forecaster feeds the computer program with information, for example, current inflation, unemployment, money supply, etc. and the expert systems re-

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[15] Ibidem.

[16] R.J. Hyndman, B. Billah, *Unmasking the Theta method*, "International Journal of Forecasting" 2003, vol. 2, p. 287–290.

[17] P. Petropoulos, K. Nikolopoulos, V. Assimakopoulos, *An expert system for forecasting mutual funds in Greece*, "IJEF" 2008, vol. 4, p. 404.

[18] A. Alasgarova, L. Muradkhanl, *Expert system for decision-making problem in economics,* "International Journal Information Technologies and Knowledge" 2008, vol. 2, p. 299.

sponds with its opinion on the dynamics of inflation and possible causes of inflation. Consequently, expert systems can extend forecasting procedures and can meaningfully assist economists.

In many cases, expert systems are found to be good at dealing with uncertainty[19]. In 1950, Alchian pointed out that uncertain and incomplete information are present in economic relationships[20]. Consequently, expert systems can fruitfully extend economic applications.

The main desirability from applying expert systems in economics arises from their ability to make use of knowledge from different sources. To illustrate this, let us predict next period's inflation. Traditionally, a regression model would be fit for this purpose. However, these models cannot directly incorporate useful knowledge from human experts. Expert systems close this gap, because they are able to combine economic data sets with knowledge from economic human experts.

Regression techniques are widely applied forecasting methods. Thus, Tab. 2compares expert system with ergression analysis to illustrate the advantages of expert systems in economics.

Table 2 Comparison of expert systems and regression analysis

Evaluation criteria	Expert Systems	Regression Analysis
Based on symptoms and causes?	Yes	No
Can deal with incomplete / uncertain data?	Yes	Partially
Combine human and statistical knowledge?	Yes	No
Can incorporate qualitative factors?	Yes	No

Source: Own elaboration.

However, benefits often entail costs. Consequently, the next section will also look at the downside of the use of expert systems in economic applications.

3. SWOT-Analysis of the use of expert systems in economics

In order to judge if the above-mentioned hypothesis has to be rejected an analysis of strength, weaknesses, opportunities, and threads (SWOT) is executed. Primary, a SWOT analysis is the most straightforward scheme that allows evalu-

[19] R. Buxton, *Modelling uncertainty in expert systems*, "International Journal of Man-Machine Studies"1989, vol. 4, p. 445.

[20] A. Alchian, *Uncertainty, evolution, and economic theory*, "The Journal of Political Economy" 1950, vol. 3, p. 211.

ating a company's strategic position[21]. However, it is also a very good tool to critically assess the application of new methods – here, expert systems in economics. The idea is not completely new. Stoia examined expert system and applied a SWOT analysis. However, he focused on business rather than economical applications of expert systems[22].

Strength:

- Expert systems are easy to build. Only a human expert, a computer, and a bit of knowledge engineering are necessary[23].
- These systems are very intuitive to be understood by humans, especially when the "if-then rule" concept is used.
- Expert systems can in corporate different sources of knowledge like time series, human experts, and economic literature.
- They are good at dealing with uncertainty and incomplete data, which is often the case in economic scenarios.

Weaknesses:

- Rules in a knowledge base can be conflicting. As a consequence, the entire system would be inconsistent and cannot be applied.
- Expert systems are limited to a finite amount of variables. For real world economic applications, an inexhaustible amount of data is available. A decision regarding inputs has to be made.
- Expert systems are limited to the amount of knowledge available[24]. Therefore, they cannot be applied to explore fields of economics where little knowledge (= data) is available.

Opportunities:

- Expert systems can provide a valid and meaningful second opinion during economic analysis.
- Knowledge base of some expert systems can be updated and refined as soon as new knowledge is available. This self-learning concept is very useful and attractive for economic applications.
- Expert systems are able to reveal insights between economic variables which might not have been discussed in literature yet.
- Expert systems can logical scrutinize existing economic models.

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[21] T. Hill, R. Westbrook, *SWOT analysis it's time for a product recall*, "Long range planning: LRP; International Journal of Strategic Management" 1997, vol. 1, p. 46.

[22] C.-L.Stoia, *A study regarding the use of expert systems in economics field*, "Procedia Economics and Finance" 2013, vol. 1, p. 389.

[23] Ibidem, p. 390.

[24] F. Alonso, L. Martínez, A. Pérez, J.P. Valente, *Cooperation between expert knowledge and data mining discovered knowledge. Lessons learned*, "Expert Systems with Applications" 2012, vol. 8, p. 7529.

– They can make use of soft knowledge with a level of confidence which is less than 100%, like humans[25]. Example: If inflation increased and unemployment rose too, inflation would rise further, with a probability of 75%.
– Expert systems can handle situations where not a single correct solution exists[26]. Example: The unemployment rate will rise with a scenario probability of 80%, and with 20%, it will remain.

Threats:

– Expert systems output the most likely scenario. Consequently, these systems might misapprehend when used in the wrong context.
– Expert system models can be over-fitted. This implies that the model works extremely well on test data but not on real data.
– If experts share deliberately bad knowledge, the performance of the system can be bad.

Conclusion

At the beginning, the hypothesis was presented that expert systems can extend traditional economic modelling. This hypothesis was evaluated by applying a SWOT analysis. All mentioned positive aspects support the hypothesis. In contrast to this, the weaknesses and threats foil the hypothesis. However, when looking more into the details, all weaknesses and threats can be treated. Weaknesses: Inconsistent probabilistic knowledge can be resolved by using HEUREKA[27]. The limitation of variables and the required availability of knowledge (= data) are not expert systems-specific and they hold for traditional forecasting procedures. Threats: Many economic forecasting procedures aremis leading when used in the wrong context. Consequently, expert systems need supervision. However, the supervisors' time is well-spent, because it also resolves the problem of over-fitting the model and the likely possibilities of experts deliberately providing bad knowledge at the same time, that is, the last open remaining threat. In total, the strengths and opportunities outperform the weaknesses and threats. Consequently, the stated hypothesis can not be rejected.

In the future there seems to be a good opportunity to build an expert system to support inflation forecasts. The phenomenon of inflation is economically well-understood, which, therefore, provides a sufficient level of knowledge. On the other hand, all involved economic variables for example, unemployment, money

[25] A. Alasgarova, L. Muradkhanl, *Expert system…*, p. 299.
[26] Ibidem, p.297.
[27] M. Finthammer, G. Kern-Isberner, M. Ritterskamp, *Resolving inconsistencies in probabilistic knowledge bases. KI 2007 advances in artificial intelligence,* "30th Annual German Conference on AI, KI 2007" 2007, p. 114.

stock, expected inflation, interest rates come with a natural degree of uncertainty. Expert systems are mighty when uncertain variables and relationships are available.

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Summary

This article presented the hypothesis that expert systems can extend traditional economic modelling. Before this hypothesis was examined, expert systems were specified and example swere given. Expert systems use a knowledge base, often of the form of "if A, then B" rules. It has been highlighted that expert systems have not as often been applied in economics as in other disciplines, like medicine or business science. A SWOT analysis for the stated hypothesis was conducted. Based on this qualitative analysis, the hypothesis was not rejected. An expert system for supporting inflation forecasts will be built in the nearer future.

Keywords: expert system, artificial intelligence, economic modelling, SWOT analysis

OCENA WYKORZYSTANIA SYSTEMÓW EKSPERCKICH W DZIEDZINIE EKONOMII

Streszczenie

W niniejszym artykule postawiono hipotezę, że system ekspercki może rozszerzyć tradycyjne podejście modelowe w ekonomii, a także, że systemy te z powodzeniem możemy zastosować do problemów ekonomicznych. Zanim przetestowano hipotezę przedstawiono przykłady zastosowań systemu eksperckiego oraz wykazano, w jaki sposób korzysta ów system z bazy wiedzy. System ten w wielu przypadkach opiera się na warunku, „jeżeli A to B". Zaznaczono także, że stosowanie systemu eksperckiego jest nieporównywalnie mniej popularne w ekonomii niż w medycynie czy w praktyce biznesowej. Przeprowadzono analizę SWOT w celu weryfikacji hipotezy. Wyniki analizy jakościowej nie pozwalają odrzucić hipotezy, system ekspercki pozwala zmniejszyć niepewność zmiennych ekonomicznych, gdy tylko dostarczymy jemu rzetelną bazę wiedzy. System ekspercki także pomógłby w prognozowaniu inflacji, dlatego ciekawym rozwinięciem powyższych rozważań byłaby budowa systemu eksperckiego wspomagająca prognozowanie inflacji.