Qualitative Economics: An Implementation in PROLOG

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Abstract. In this paper, we describe a formalism for qualitative reasoning in economics. The framework may serve as a common basis for the intuitive reasoning practised by experienced economists and the more formal qualitative models recently established in the field of artificial intelligence. The emphasis is on representation and implementation aspects of qualitative models. The formalism is illustrated in a well-known Keynesian model.

Key words. Qualitative reasoning, expert systems, macroeconomics.

1. Introduction

The developments in qualitative modelling originate mainly from AI research in the field of 'naive' physics (Forbus, 1986; Hayes, 1979; de Kleer and Brown, 1984; Kuipers, 1986). The aim of 'naive' physics is to provide a description of physical devices in qualitative terms in such a way that only crucial distinctions in qualitative behaviour are preserved. In addition, there are also some contributions in the fields of electronic circuit analysis (Davis, 1984; Genesereth, 1984) and medical diagnosis (Chandrasekaran and Mittal, 1983; Kuipers and Kassirer, 1984). Recently, researchers have started to consider the exploration of these ideas in economics which has led to some interesting results. For example, the differences between quantitative and qualitative models are illustrated by the classical macro-economic theory of output and employment in Farley (1986). Constraint propagation techniques are applied to a model concerning the equilibrium of the commodity and labour market in Bourgine and Raiman (1986). In Pau (1986), qualitative arguments occurring in government texts addressing economic subjects are mapped into a formal grammar.

Application of AI methods undoubtedly contributed to the understanding of economic reasoning. However, some of the underlying ideas in qualitative modelling have already been published in the economic literature. The similarity between the theory of confluences (de Kleer and Brown, 1984) and comparative statics (Samuelson, 1947) is pointed out in Iwasaki and Simon (1986a) and a profound treatment of qualitative statics can be found in Greenberg and Maybee (1981).
The reexploration in the application of formal qualitative modelling in economics is mainly due to the tremendous increase in computer power and the proliferation of symbolic programming languages such as LISP and PROLOG. One of the intrinsic reasons for studying qualitative methods is the lack of consistent data that are indispensable in quantitative models. A practical reason is the intractability of the huge amounts of computer output of complex numerical models. Other reasons are the wish to create automatic procedures for tracing causal chains, and to provide procedures to support the validation of the structure of economic models (Boutillier, 1984; Fontela, 1986; Gallo and Gilli, 1990; Royer and Ritschard, 1984). In any case, we believe that qualitative modelling provides a way of filling the gap between number crunching programs and verbal intuitive reasoning (Paliès and Philip, 1989; Berndsen and Daniels, 1989a).

In this paper, we propose a constraint oriented approach to qualitative modelling. The method can be positioned somewhere between the theory of qualitative reasoning based on confluences (de Kleer and Brown, 1984) and qualitative simulation (QSIM) (Kuipers, 1986). The main differences emerge from the fact that these theories were developed to study the qualitative behaviour of physical systems. In the formalism proposed in this paper, qualitative dynamic models consist of standard symbolic constraints (e.g. originating from balance sheet equations), constraints representing contemporaneous causality (if two economic entities influence each other directly) and sequential causality (if the influence is unidirectional and there is a time lag involved (Hicks, 1979)).

Explicit modelling of causality seems quite natural in economics. In earlier papers (Iwasaki and Simon, 1986a, 1986b; de Kleer and Brown, 1986), causal relations are derived from a static mathematical model. It can be shown that causality derived from static models by the methods of causal ordering or mythical causality does not reflect the intuitive notion of causality (Iwasaki, 1988; Berndsen and Daniels, 1989a). One way to get around this problem is to consider dynamic models (Iwasaki, 1988). However, we believe that dynamic models possess a level of detail which is unnecessary to describe the qualitative behaviour of economic systems. Therefore, we start from a declarative representation of causality based on economic theory. Similar ideas have been considered in the description of physical devices (Rieger and Grinberg, 1977).

In Section 2, the formal semantics of the constraint language is described. An implementation in PROLOG is discussed in Section 3. In Section 4, a Keynesian model is presented.

2. Qualitative Modelling

2.1. FORMALISM

In the following, an economic system $\mathcal{S}$ is defined as:

(i) a set of variables $V = \{v_j\} (j = 1, \ldots, n)$,