Boundedly Rational Qualitative Reasoning on Comparative Statics

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Abstract: Policy discussions often are almost entirely based on qualitative arguments. The structure of the underlying mental models can be described by the notion of a causal diagram. This is exemplified by the analysis of the Newsweek article "Saving, Not the American Way" by Rich Thomas.

1.   Introduction

It is the purpose of this paper to throw light on the structure of verbal economic reasoning as we find it in newspaper articles on questions of economic policy or in the non-mathematical economic literature. Presumably, the thinking of practical decision makers in business and public administration has a similar structure. A better understanding of this structure seems to be important for the development of a realistic theory of boundedly rational economic behavior.

In verbal economic reasoning one often finds statements of the following kind: "An increase of X causes an increase of Y" or "An increase of X causes a decrease of Y". Such descriptions of causal relationships are **qualitative** in the sense that they concentrate on directions of change; nothing is said on the quantitative strength of the effect.

Qualitative reasoning directly proceeds from qualitative assumptions to qualitative conclusions. In this connection, it is necessary to emphasize the word "directly". Mathematical modeling may also pursue the goal to reach qualitative conclusions on the basis of quantitative assumptions. Sometimes theorists do not want to determine more than the sign of partial derivatives with respect to parameters. Qualitative reasoning avoids the intermediate step of formulating a qualitative model.

A Bayesian decision maker has no use for qualitative reasoning. In order to find the decision parameters which maximize expected utility, one needs a quantitative model and a subjective probability distribution over its unknown structural parameters. Purely qualitative information is usually insufficient. Nevertheless, even mathematical theorists aim at qualitative conclusions. This suggests that such conclusions are valuable for decision makers in view of their boundedly rational decision procedures. A boundedly rational decision maker may be primarily interested in the question in which direction a decision parameter should be adjusted. After the answer to this qualitative question has been obtained, the parameter can be adjusted cautiously in the indicated direction.

Qualitative reasoning does not mean that quanitative information is completely ignored. The selection of those causal relationships which are taken seriously may be guided by quantitative information. Thus, the influence of some variables may be neglected in view of their quantitative insignificance. In fact, statistical figures are often mentioned in verbal discussions but mostly in order to argue that something is important or unimportant. Only rarely, such numbers are combined and manipulated by arithmetical operations.

In this paper, attention is concentrated on qualitative reasoning about comparative statics. Qualitative reasoning can also be applied to dynamic problems but not much will be said about this here.

In the psychological literature, the idea has been proposed that human reasoning is based on mental models (Gentner 1983, JOHNSON-LAIRD 1983). In the next section, the concept of the causal diagram will be introduced. Causal diagrams can be looked upon as mental models underlying qualitative reasoning on comparative statics. They can also be described as belief systems composed of simple qualitative statements.

The view of qualitative reasoning proposed here will be exemplified by the Newsweek article "Saving, Not the American Way" by Rich THOMAS (Newsweek, January 8, 1990, p. 42-3).

2.   The concept of a causal diagram

Consider a policy question like the following one: What happens if the income tax rate is increased? In order to answer such questions by qualitative reasoning, one needs a qualitative belief system. In this paper, we shall restrict our attention to qualitative belief systems formed by a finite set of simple statements of the form (a) or (b).

> (a) Ceteris paribus a change of x causes a change of y in the same direction.
> (b) Ceteris paribus a change of x causes a change of y in the opposite direction.

In the case of (a) we speak of a **positive influence** of x on y, and in the case of (b) of a **negative influence** of x on y.

A qualitative belief system composed of a finite set of statements of the form (a) or (b) can be described by a causal diagram. Formally, a **causal diagram** is a finite signed and directed graph with some additional properties that are specified later. The full definition will be given after the introduction of some auxiliary notions.

The nodes $x, y, \ldots$ of a causal diagram correspond to variables, and a directed link from x to y represents a causal influence. The influence is positive if the sign is "+" and negative if it is "–".

A **causal chain** from x_1 to x_n is a sequence of at least two nodes $x_1, \ldots, x_n$ together with n-1 links from x_i to x_{i+1} for 1, .. n-1. A causal chain is called **positive** if the number of its links with a negative sign is even, and it is called **negative** if this number is odd. A **loop** is a causal chain with the property that $x_1 = x_n$ holds for its nodes $x_1, \ldots x_n$.

Qualitative reasoning on the basis of a causal diagram is little more than the evaluation of signs of causal chains. We say that x exerts an **indirect causal influence** on y if there is at least one causal chain from x to y. This influence is **positive** if all causal chains from x to y are positive, and **negative** if all these chains are negative. It may also happen that the diagram exhibits positive as well as negative causal chains from x to y. In this case, we say that x has an **indefinite** influence on y. An indefinite influence does not justify a conclusion of the form (a) or (b). Positive and negative causal influences are **definite**. A causal diagram is called **balanced** if all indirect causal influences are definite.

A causal diagram need not be balanced. However, indefinite indirect influences do not provide answers to qualitative policy questions. Therefore, one can expect that belief structures described by causal diagrams are formed in a way which avoids indefiniteness as far as possible, at least where it matters for decision makers. This works in the direction towards balancedness.

The graph structure of a causal diagram has to be complemented by additional information about the strategic possibilities and the motivation of the decision maker. In order to describe the strategic possibilities, a subset of the nodes of the causal diagram is specified as a **set of instruments**. An instrument represents a variable controlled by the decision maker. An instrument x must have the property that no direct causal influence is exerted on x .

In order to describe the motivation, a subset of nodes must be specified as a **set of goals**. Goals are interpreted as variables whose increase is valued by the decision maker. In this paper, attention will be concentrated on the case of only one goal. In the presence of several goals, one would have to answer the question how goal conflicts are solved in qualitative decision making. One could try to do this with the help of aspiration adaptation theory (SELTEN 1998). No attempt in this direction will be made here since our subject matter is qualitative reasoning rather than decision making.

We now present a formal definition of a causal diagram.

Definition: A **causal diagram** is a finite signed and directed graph together with two non-empty subsets of nodes, a set of **instruments** and a set of **goals**. The following conditions must be satisfied:

(a) There is at most one link from one node to another.

(b) There are no loops.

(c) An instrument is a node x such that there is no link from a node y to x (however, not all such nodes must be instruments).

(d) For every instrument x there is at least one causal chain to a goal y.

Condition (a) means that the direct ceteris paribus influence of one variable on another is unambiguously specified. The absence of loops required by (b) is a property which has been observed by AXELROD in his studies on qualitative reasoning in his book "Structure of Decision" (1976). AXELROD does not look at causal diagrams but at undirected signed graphs which are used to describe opinions expressed by speeches of politicians. The use of such graph structures for the purpose of representing opinion structures goes back to the paper "Symbolic psycho-logic" by ABELSON and ROSENBERG (1958). Maybe the most striking result of AXELROD was the absence of loops. The causal diagram does not just represent positive and negative connections but it also expresses causal relationships by the directions of links. An instrument is thought of as a variable controlled by the decision maker. It is therefore natural to require that no causal influences other than the will of the decision maker are exerted on an instrument.

In my paper of 1967 (SELTEN 1967), the definition of a causal diagram was further restricted by the condition that there should be no influences on other variables exerted by goals. This condition seems to be unnecessarily restrictive and is therefore not a part of the definition proposed here.

An instrument without any indirect influence on any goal would be irrelevant for decisions on policy questions. Therefore, condition (d) which was absent in SELTEN (1967) is included in the definition of the causal diagram. One might want to require the stronger property that every instrument indirectly influences every goal but this would be unnecessarily restrictive. In fact, a study by WILLIAMSON and WEARING (1996) indicates that economic opinions of lay people are often described by diagrams with several components without any connection to each other.

WILLIAMSON and WEARING investigate the economic opinions of many lay people in Australia and received very interesting results. In their highly remarkable paper, they describe "cognitive models" similar to causal diagrams but also different in important respects. Thus, not only variables but also "needs" like "government should encourage Australians to work" are

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represented as nodes of the graph. Links may express relatedness or unrelatedness besides positive or negative causal connections. In this way WILLIAMSON and WEARING obtain a close agreement with the verbal statements of their subjects. The concept of a causal diagram restricts itself to positive and negative causal links between variables. In this way, one obtains clear qualitative descriptions of the perceived causal structure. The causal diagram is a mental model about the underlying reality rather than a detailed elaboration of all opinions including evaluations and action recommendations.

The basic idea of a causal diagram is very simple and I would not be surprised by being told that it can be found in the literature before 1967. In the newer literature sometimes explicit use of causal diagram is made, e.g. in the book by Frederic VESTER (1990) "Ausfahrt Zukunft". However, VESTER adds an additional feature to the causal diagram which is not really qualitative. Each link has a degree of strength. There are finitely many levels of this degree of strength.

The fact that there seems to be a widespread use of causal diagrams and similar graph structures suggests that it is a natural tool for the description of qualitative causal reasoning. It is maybe necessary to pay more attention to this formal structure even if it is a very simple one.

3. The causal diagram of a Newsweek article

Figure 1 shows a causal diagram constructed on the basis of a Newsweek article (January 8, 1990) with the title "Saving, Not the American Way" by Rich Thomas. Before this diagram can be explained in detail it is necessary to say something about the structure of this Newsweek article. First, it is shown with the help of statistical figures that the U.S. savings rate is very low in comparison to Germany and Japan. In view of this situation, it had been proposed to create new tax incentives for saving.

In the diagram, the only goal variable considered is growth even if in the text the word "growth" is not explicitly mentioned. However, after the discussion of the high savings rate in Germany and Japan, we can find the following remark:

"Has this saving led to better living standards? In Germany, incomes have increased over the past 20 years, inflation is negligible and the Deutsche Mark has become Europe's most powerful currency. Japan, too, has emerged as an economic superpower."

Since living standards are connected to growth it seems to be justified to look at growth as the goal variable. The text focusses on investment rather than growth. But it seems to be implicitly assumed that an increase of investment leads to a higher growth rate. Therefore in the diagram, the influence of investment on growth is positive.

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In the diagram, some of the influences are indicated by lines with fully black arrow heads. The variables tax incentives for saving, savings, funds available for investment, interest rate, investment and growth as well as the lines with fully black arrow heads reflect the main argument for a positive indirect influence of tax incentives for savings on growth. We refer to this part of the diagram as the **main diagram**.

The lines with arrow heads which are white on the inside represent other influences and critical objections against the main argument. In most cases these influences involve variables outside the main diagram.

A "+" or "–" at a line representing a direct influence indicates whether this influence is positive or negative. Numbers indicate quotations which support the concerning influence. The quotations are shown below the diagram in Figure 1.

The main diagram has two positive causal chains from the instrument variable "tax incentives for saving" to the goal variabe "growth". Obviously, the main diagram is balanced. If the causal chain from savings over consumption on growth were not be dismissed by quotation 4), the balance of the main diagram would be destroyed, since, then, tax incentives would have a negative influence on growth via the causal chain involving consumption.

We now discuss the influences of the causal diagram following the numbering of the quotations. Tax incentives for savings supposedly have a positive influence on savings. This is clearly indicated by quotation 1). The causal chain from "savings" over "funds available for investment" to "investment" reflects quotation 2). The causal chain "savings" over the "interest rate" to "investment" is suggested by quotation 3) even if the second influence from the interest rate to investment is not explicitly mentioned. However, the words "making it chaeper to borrow in the United States…" suggest that more will be borrowed and invested if interests are lower. We already have discussed the influence of investment on growth which is implied by the text but not explicitly expressed by the text. Quotation 4) also gives a hint to growth as a goal because it is judged as a bad side effect that curbing consumption would drag the economy into a recession.

After having discussed the main diagram and the dismissed causal chain from "savings" over "consumption" to "growth", we now turn our attention to the remaining causal influences.
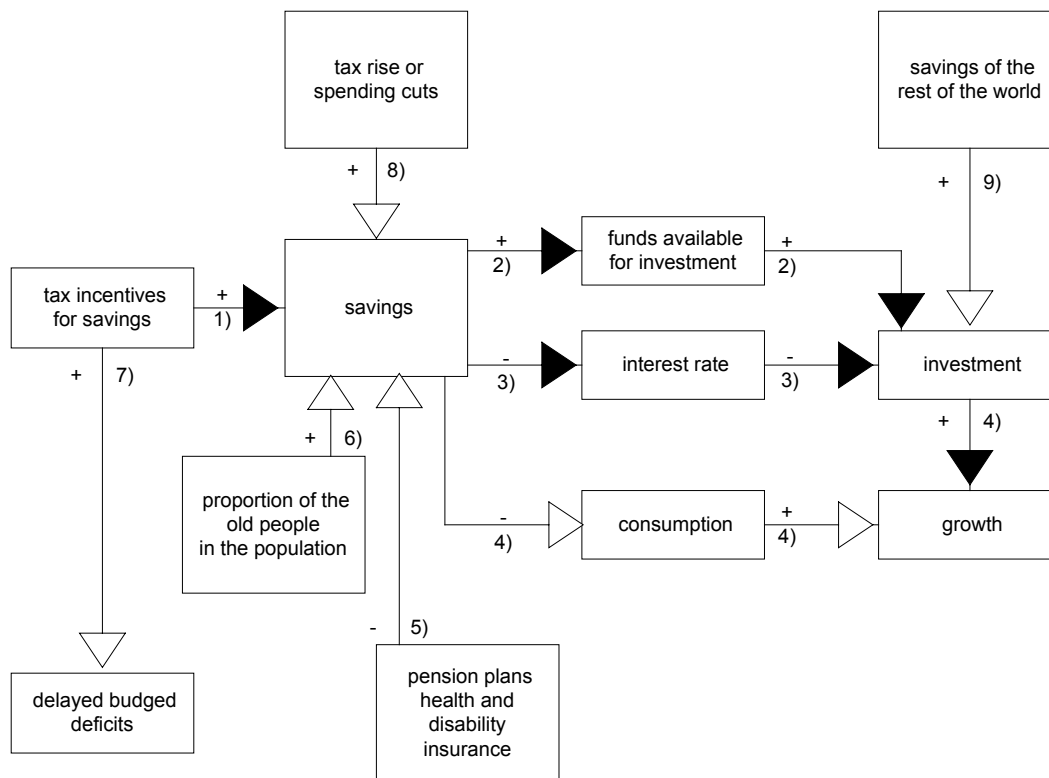
Quotations:

1) Tax law which generally benefits borrowing far more than saving and is in part responsible (for the decline in savings). … Most of the coming proposals assume that tax policy can motivate people to save more.

2) Savings regardless where deposited act as a pool of money that businesses can tap for new plants, equipment and employees.

3) Greater savings keep interests lower, making it cheaper to borrow in the United States.

4) Because of these advantages (2 and 3), most economists dismiss the commonly held view that curbing consumption would drag the economy into a recession.

5) In addition, the slide in savings is "a byproduct of our social progress" says Harvard economics Professor Lawrence Summers. The spread of pension plans, health and disability insurance and large increases in social security benefits have vastly reduced the need of many Americans to save, ...

6) Edward Yardeni of Prudential-Bache Securities Inc. says the aging population will push the savings rate above 10 percent.

7) Critics say the plan would eventually cost the treasury billions of dollars. "What you're really doing is planting a lot of delayed budget deficits… says Henry Aaron of the Brookings Institution".

8) Critics like Aaron believe that tax incentives are a poor way to attack the low savings rate in any case. They argue that balancing the budget - a tax rise or spending cuts - would accomplish the same aims.

9) John Makin of the American Enterprise Institute says that the rest of the world is saving so much and investing it in this country that the U.S. savings rate isn't as relevant as before.

Figure 1: Causal diagram of the Newsweek article and quotations

The negative influence of "pension plans etc." on "savings" is offered as an explanation for a lower savings rate compared to a time in the past with less social security. Of course, this explanation is dubious in view of the fact that the social security system of Germany is by no means less well developed than that of the United States.

One of the critical remarks reported in the article was the objection that tax incentives for savings create delayed budget deficits. This means that attention is directed to future budget balances as a second goal neglected by the main argument.

Another objection is based on the opinion that the growing proportion of old people will lead to an increased savings rate and that therefore tax incentives are not necessary. A third objection recommends a tax rise and a spending cut instead of tax incentives in order to raise savings understood as including not only private but also public savings or dissavings.

A fourth criticism points to the importance of foreign savings for investment and denies a significant influence of domestic savings. The positive influence of consumption on growth is also mentioned as a possible counterargument. The balancedness of the main diagram would be destroyed by the inclusion of this influence.

4.   Concluding remarks

The article by Rich Thomas "Saving Not the American Way"discussed above is very well reasoned and therefore naturally lends itself to the description by a causal diagram. Unfortunately, not every journalist writes that well. In many newspaper articles it is hard to find any reasoning. However, the author has found it useful to translate discussions of policy questions into causal diagrams and has taught this technique in courses on bounded rationality. The causal diagram formalizes the structure of qualitative reasoning about comparative statics.

Theories of qualitative reasoning about dynamical systems have been proposed in the artificial intelligence literature (BOBROW 1985). The articles collected in the book by BOBROW concern physical systems but the method can also be applied to economic systems. In fact, the old business cycle theories before mathematical models became popular were almost exclusively based on qualitative arguments. The methods described in the book by BOBROW throw light on these theories. It would be interesting to say more about qualitative reasoning on dynamic economic systems but this cannot be done here. The author hopes that he will be able to do this elsewhere.

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