THE REACTION ENGINE

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Abstract

The engine of economical phenomena is human action. The reaction engine, presented here, exploits this fact by explicitely making human action the cause of all changes in the case of a market economy. This offers a natural way of grounding causal reasoning about economical phenomena.

First this paper shows the limitations of the classical framework of Comparative Statics. Second it motivates the introduction of causal reasoning by higlighting the disambiguating power of causal arguments found in economic textbook. Third it shows how the reaction engine encodes causal reasoning, and and takes advantage of it, to enhance reasoning about economical phenomena.

Introduction.

The interest for Qualitative Economics is not a new one. [10] . The main framework which uses a qualitative calculus to reason about economical phenomena is known as Comparative Statics.

This framework encounters sever limitations as explained in the first part of this paper. This part shows that this framework makes relatively poor use of qualitative reasoning techniques. In particular it cannot perform causal reasoning.

Introducing causal arguments is a difficult topic as has shown previous attempt to perform qualitative reasoning about physical phenomena [3, 4, 5, 8, 9]. The second part of this paper shows that the nature of economical phenomena allows to set *causal* reasoning for economics on firmer grounds. This can be done due to the nature of economic phenomena where the concept of human action takes all it's importance. The engine of economical phenomena is human action. The word ***interaction*** takes its full meaning, and the concept of causality, as the result of human action becomes a powerful technique to figure out the cause of all changes.

This second part of the paper motivates the introduction of causal reasoning for economics. It takes as reference R.J. Barro's remarkable textbook, *Macroeconomics* [1] to point out through an example how causal reasoning can potentially enhance qualitative reasoning by:

- Removing ambiguities
- Dealing with feedback

The third part of this paper introduces the Reaction Engine. This part explains how the link between causal reasoning and human action can be explicitely embedded.

I Qualitative economics and Comparative statics.

To understand how a system work's, a general idea is to study how it reacts to a perturbation. Comparative Statics is a formal tool well known by Physicist's and Economists, [10] which helps to achieve this goal[1]. To point out the close link, which is often made between Comparative Static and qualitative reasoning, one might consider the following example:

Ia A supply shock

Consider A simple economy, where there is a supply Ys and a demand function Yd for commodities; a supply M/P and demand Md function for the quantity of money. The interest rate is noted R the average price level for commodities P
A perturbation is introduced in the commodity market, and is represented by the exogeneous parameter u (for instance caracterising consequences of a sudden drough in agricultural economy).

$$Ys(R,u) = Yd(R,u)$$

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[1] For example Van't Hoff law in Chemistry can be derived from Comparative Statics

$$M/P = Md(Yd,R)$$

Differentiating these relations, leads to a set of linear equations linking the changes of the different parameter to the change in the shift parameter u.

$$dR + du = - dR + du$$

$$dM - dP = dY - dR$$

Comparative Statics, makes use of a qualitative calculus when solving these differential equations without relying on the numerical values of the different partial derivatives.

Ib The scope of Comparative Statics

It is worthwhile to carefully examine the underlying assumptions that are made about a process in order to make Comparative Statics a relevant tool to study it's behavior.

1. The word *Statics,* in Comparative Statics, stands for the assumption that the process considered has attained it's Equilibrium. Therefore the scope of Comparative Static, is constraint by the underlying assumption that an equilibrium arises.

2. The word *Comparative,* expresses that the reasoning will involve only comparison between equilibriums. In other words the causes and the regulation process that may lead from a disequilibrium point to it's potential equilibriums are not described.

3. Differentiating equilibrium relations relies on the assumption of *Quasistatic evolution.* This is another constraining assumption. it limits the scope of validity of this approach and does not correspond to qualitative reasoning requirements.

4. It cannot deal with one of the most important issues for economic phenomena the *regulation process.* To handle regulation process it is necessary to handle feedback. This cannot be perform within a Quasistatic Assumption which only describes sequence of equilibriums. The Quasistatic Assumption cannot handle disequilibrium path. Thus, it cannot deal with the consequence of a shock on an economy. As a consequence the Comparative Statics framework lacks causal reasoning which would provide *histories* describing causal disequilibrium paths in a regulation process.

II Beyond Comparative Statics

R.J. Barro in his remarkable textbook Macroeconomics goes beyond Comparative Statics by performing causal reasoning. The causal reasoning is based on the interaction of Microeconomic foundations of Macroeconomic phenomena. Macroeconomic phenomena results from aggregation of the action of micro economic agent's action. This grounding of causality can be used to disambiguate among different macroeconomic behaviors. For instance in the case of a temporary downward shift of the production functions the comparative static model given above of a simple economy is ambiguous as far as the change of the interest rate is concerned. In his book R.J. Barro removes the ambiguities by presenting a history concerning the disturbance path induced by the shock. This history can be summarized as follows:

Assume initially, that the interest rate R, has not changed. Then economic agents increase increase a little their work effort leading to a little more supply of commodities ys and reduce a little their in consumption yd, (because R is small, $R << 1$). The aggregate effect Ys, Yd offsets only part of the initial cutback in supply Ys. Thus there would be an excess of demand compared to supply $Yd > Ys$, and the market does not clear.
Therefore to clear the market the interest rate R will then also have to rise. Since the quantity of money must be willingly held, and the interest rate increases, and the output decreases than the price level P must increase.

The causality embedded in this interpreation allows to disambiguate among potential macroeconomic behavior consistent with the comparative statics model given above. This motivates to introduce a framework that would embed such kind of causal arguments. But it is important to notice that the history presented above is still kind of hybrid and must be set on firm grounds. It is hybrid for the following reasons: explanation for instance:

1. If we try to find an interpretation for these different steps and still assume that the market always clear; then the first step is a virtual point since the equilibrium cannot be satisfied without an increase of the interest rate R.

2. The only justification, for the change of the interest rate is an indirect proof.

3. The change for the value of the interest rate is not explained by the result of economic agents action, but due to the necessity to remain at equilibrium

III A flavor of what can be achieved

The two previous sections have shown the limitations of Comparative static and the motivation for introducing causal reasoning based on explicit integration of human action through microeconomic foundations of Macroeconomic phenomena. This section introduces the Reaction Engine framework which has been built to explicitely take advantage of causal reasoning. It tries to give a flavor of what Qualitative Economics can attain. More precisely, the framework described in this section copes with the following limitations:

1. It avoids indirect proofs which are not satisfycing for causal reasoning

2. It does not require that markets always clears, and therefore it does not imply an assumption of Quasistatic Evolution.

3. It does not require that the market will eventually clear. Therefore it does not require that the process finally reaches an equilibrium and the algorithm in that sense is not deterministic, although it does not rule out that an equilibrium is eventually reached;

4. It allows to reason about feedback and regulation process.

The decomposition of the process can be viewed as two [2] worlds that act upon each other. The world of an "average" Economic agent, and it's External world, ie his environment the macroeconomic phenomena.

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[2] More worlds or elements can be added when more complex actors are to be considered

- The environment acts on the the economic agent by constraining his choices and influencing his decisions.
- When a decision is taken by an economic agent, if it is followed by an action, it is aggregated, and modifies the environment.

The evolution process of a market economy is described by a sequence of such elementary interactions between these two worlds:

(1) Start with an initial environment
(2) Find the reaction of an economic agent in this environment.
(3) If there is an action aggregate it go to (2). else stop.

IIIa Microeconomic world

The economic agent acts as if he cannot influence the value of macroeconomics parameter *Ys*, *Yd*, *R*, *P*, *Ms*. The economic agent can only act on extensive parameters at the microeconomic level: his supply and demand functions noted ys, yd, md, ms. The reaction of an economic agent to a given environment is viewed as a particular kind of problem solving process. The agent has to satisfy a budget constrained over time (expressed qualitatively using order of magnitude relations and sign algebra). [11] The economic agent makes his choice among difference potential reactions satisfying his budget constraint by relying on a set of preferences. For instance there is a trade-off between leisure consumption, between working now versus later. This part has been described in [7]. The important point is that the model of an economic agent is qualitative and does not assume that he optimize a utility function. Instead the economic agent preferences are given through a set of qualitative rules of behavior.

IIIb Aggregation Process .

The aggregation process is based on the law of supply and demand. Intensive parameters such as the Price level P, resp. the interest rate R, increase or decrease depending whether demand exceeds supply on the commodity market, resp the monetary market. Extensive parameters such as *Ys*, *Yd*, *Md*, are aggregated in a straightforward manner following the action of an average economic agent. if ys increases than Ys increases and so on.

More sophisticated means of aggregation [6] could be considered but are beyond the scope of this paper.

IIIc Macroeconomic World

The Macroeconomic parameters follow the change resulting from the aggregation of microeconomic actions. During the evolution process these changes need not to satisfy equilibrium relations; an equilibrium is only reached if it is the result of a sequence microeconomic actions.

IIId The supply shock revisited

Let us reconsider the example of the simple economy and consider the case of supply shock within the Reaction Engine framework.

Step1: Initial Environment: Downward shift of the production function.

$\delta Y_s = -$ Given
$\delta Y_d = 0$ Given
$\delta P = 0$ Given
$\delta M_s = 0$ Given
$\delta M_d = 0$ Given
$\delta R = 0$ Given

Step2: Economic agent's reaction: Small negative wealth effect.

$\delta y_s = +$
$\delta y_d = -$
$\delta y_d < < \delta y_s$
$\delta M_d = +$
$\delta M_s = 0$

Step3: Aggregation:

$\delta M_d = +$
$\delta M_s = 0$
Thus: $\delta R = +$

$\delta Y_d < < \delta Y_s$
and $\delta Y_s = -$
Thus: $\delta P = +$

Step4: Reaction of economic agents: Significant increase in supply and decrease in consumption of goods.

δy_s[12] Co δy_d
$\delta y_s = +$
$\delta y_d = -$
$\delta m_d = -$
$\delta m_s = -$

Step5: Final environment: Interest rate rises price level rise regulating the commodity market.

$\delta R = +$
$\delta Y_s = -$
$\delta Y_d = -$
$\delta Y_d \quad \delta Y_s$
$\delta P = +$
$\delta M_d = -$ and
$\delta M/P_s = -$

It is important to notice that the reaction engine provides the same final state as the one given by R.J. Barro's book without rtelying on the assumption that the markets clear.

IIIe Feedback

An essential property of this tool is it's ability to reveal feedback, which is crucial for the understanding of a regulation process. The first loop of the in the example above describes a negative feedback as far as supply of commodities is concerned: The economic agent reacts to the supply shock, by increasing to some extent it's work effort, which partially reduces the initial cutback in supply. In the same way there is a feedback of the environment to the demand of money of the economic agents, due to the increase of interest rates.

IIIf Chaotic behaviors

The representation of the environment and the representation of an economic agent's behavior are described as separate parts. It is possible to reason about the beliefs that an economic agents has about it's environment. In the example above the underlying assumption is that the agents are aware that the supply shock is temporary. But with such a formalism it is possible to consider the same initial situation and assume that the agent believe that the shock is permanent. The reaction engines does not apriori assumes that there will be a negative feedback. Thus it can potentially lead to chaotic behaviors.

IV Summary

This paper shows how qualitative economics can be enhanced by explicitly using a link between causality and human action. In the reaction engine the link between human action and causality is emphasized and allows to capture feedback and regulation process. If grounding causal reasoning about physical phenomena is still a difficult issue. For economical phenomena the natural link between change and human action allows to take a better advantage of causal reasoning.

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