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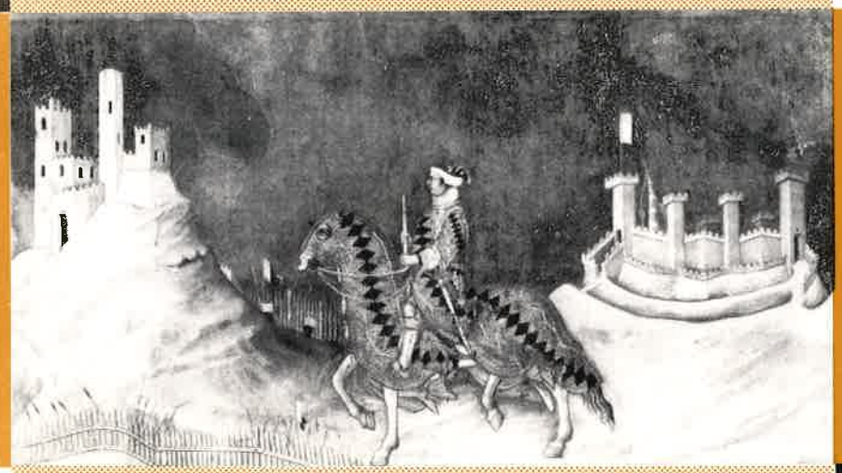
QUADERNI DELL'ISTITUTO DI ECONOMIA

Alessandro Vercelli

PROBABILISTIC CAUSALITY AND ECONOMIC MODELS: SUPPES, KEYNES, GRANGER



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PROBABILISTIC CAUSALITY AND ECONOMIC MODELS: SUPPES, KEYNES, GRANGER

Siena, novembre 1986

"As our knowledge is partial, there is constantly, in our use of the term cause, some reference implied or expressed to a limited body of knowledge."

(J.M. Keynes, 1921, p. 306)

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1. Introduction

Causality concepts have played since the early fifties an important role in economics. They have been involved in many theoretical and methodological debates as well as in the appraisal of alternative theories and models.

At the roots of the modern notions of causality in economics we find authors like Keynes, who used often causal concepts in his economic contributions, and Tinbergen, who gave a version of "process analysis" particularly suitable for a causal analysis. A crucial step for working out a notion of causality rigorous and general enough for economic analysis was taken in the late forties and early fifties when causality was redefined in the language of matrix algebra which was going to find a widespread application in economics. A seminal contribution in this direction came by R. Goodwin (1947) who was able to clarify the relation between "unilateral coupling", as he preferred to call what was going to be called a "causal relation", and the formal properties of matrices necessary to express it[(1)]. This contribution inspired the papers written in the early fifties by Simon (1952, 1953, 1954) who built on the suggestions of Goodwin[(2)] adopting explicitly a causal language and referring openly to the philosophical literature on causality. Simon's notion of causality rapidly became the most influential notion of causality in economics up to very recently. It is only in the early seventies that its dominance has been challenged by the notion worked out by Granger (1963, 1969, 1980) and developed by Sims (1972, 1977). This notion has been considered congenial by many New Classical Economists trying to undo the Keynesian revolution, while that of Simon has often been considered congenial -broadly speaking- by Keynesian economists[(3)]. Causality concepts are thus crucially involved in the current lively debate on the foundations of macroeconomics.

In order to clarify a few aspects of this debate I wish to utilize in this essay the rigorous notion of probabilistic causality recently worked out by the well-known epistemologist P. Suppes (1970) with the aim of explicating[(4)] the causality notions of Keynes and Granger.

I will argue in particular that:

a) the causality notion of Keynes is probabilistic and anticipates in many respects Suppes causality;

b) Granger's notion of causality is *prima facie* philosophically legitimate (which was denied, among others, by Zellner, 1979), since it may be interpreted in its turn as a version of Suppes probabilistic causality, but its application to economic models is philosophically questionable;

c) there is no ground for believing that Granger causality should be preferred, generally speaking, to Simon's causality in economic analysis.

2. Suppes probabilistic causality

Probabilistic causality has occupied a central place in the philosophic debate on causality since the publication in 1970 of a monograph by Suppes that rapidly became a classic of epistemological literature. Probabilistic causality has thus a very short history notwithstanding a few earlier seminal contributions which however remained completely neglected (Reichenbach, 1956; Good, 1961-62; and, as we will see, Keynes, 1921). This might appear at first sight quite surprising because both ingredients of the concept have been on the stage of philosophical debate since long (more than two millenia for causality and more than two centuries for probability). This may be ascribed to the fact that causality and determinism have been considered an indissoluble pair up to very recently until the quantum physics revolution (initiated in the thirties) had the time to percolate in the common wisdom and the probabilistic language (after the axiomatization by Kolmogorov in 1933) began to become sophisticated enough to fit the subtleties of causal language.

It is rather early to attempt a full appraisal of the fecundity of probabilistic causality in single disciplines, like economics. What is needed is a preliminary work of development and adaptation to the specific exigencies of economic analysis. Suppes notion is particularly fruitful for this purpose because its point of view is taxonomic rather then prescriptive.

The starting point of his analysis is not, as it was typical in earlier literature, a stipulative definition of causality proposed as the paradigm for a correct use of the concept. All the attempts in this direction proved not very successful because the application scope of each of these concepts was shown to be very narrow as compared to the broad variety of meanings that may be found in scientific languages.

Suppes thus prefers to start from a "weak" notion of causality that may be considered as the "least common denominator" of a wide variety of causal notions. This is considered as a necessary premise for articulating the definition and the ensuing causal analysis in diverse directions to fit the different characteristics of many subjects and languages. This approach agrees very well with a discipline like economics where the causal intuitions are particularly varied and heterogeneous.

The starting point is the concept of *"prima facie* cause" that may be roughly defined in the following way: "An event B is a *prima facie* cause of an event A if and only if (i)B occurs earlier than A, (ii)the conditional probability of A occurring when B occurs is greater than the unconditional probability of A occurring". In other words, the occurrence of the event B increases the probability of the occurrence of the event A. *Prima facie* causality is thus a necessary, though not sufficient, condition for identifying a peculiar causal relation. Such a weak concept is unable to discriminate between "genuine" causes and "spurious" causes because even spurious causes appear to increase the probability that the effect occurs.

In order to discuss this and the following problems, we have now to introduce a definition of *prima facie* causality slightly more precise. Let us assume that A_t and $B_{t'}$ are events defined as "subsets of all the possible outcomes", i.e. in the meaning, introduced by Kolmogorof (1933), of the mathematical theory of probability. In addition, let assume that the events are referred to a well-defined instant of time. We may thus introduce the following definition:

(1) B_t is a *prima facie* (potential) cause of $A_{t'}$ as regards the background information $Z_{t'}$ iff

(i) $P(B_t \cap Z_t) > 0$ and $t < t'$

(ii) $P(A_{t'}/B_t \cap Z_t) > P(A_{t'}/Z_t)$

This definition is identical to that put forward by Suppes (1970), but for two specifications, implicit in Suppes, that are particularly relevant for what follows.

First of all we made explicit that *prima facie* causality does not necessarily presuppose the actual occurrence of events. This allows a congrous utilization of Suppes causality inside an explicit theoretical context because the concept becomes applicable not only to single events but also to types of events and not only to directly observable magnitudes but also to dispositions. As is generally agreed, types of events and dispositions are essential ingredients in any theoretical argument(5).

In addition we made explicit, from the very outset, that in Suppes approach any causal statement and inference is always relative to a *corpus* of information organised by theoretical hypotheses which we may define "background information". This should be kept firmly in mind in order to understand the nexus among the notions of causality of Suppes, Keynes and Granger.

We are now in a position to analyze the distinction between genuine and spurious causes. Let us begin by the examination of a couple of examples. One of the favourite examples of spurious cause, at least since Laplace, is that of the barometer. The sudden shift of the barometer pointer is a *prima facie* cause of the storm breaking out after a while, because the first event induces an upper revision of the probability of the second event. The barometer variation is not a genuine cause of the storm because, as is well-known, both events are effects of a third one, the fall of the atmospheric pressure. In other words, as soon as we take account of the common cause, the effect becomes stochastically independent of the spurious cause. In Reichenbach's terminology, the common cause *screens off* the *prima facie* stochastic influence of the spurious cause (Reichenbach, 1956). This suggests the following definition:

(2) B_t is a *spurious* cause of $A_{t'}$ iff

(i) B_t is a *prima facie* cause of $A_{t'}$

(ii) there is a $t'' < t$ and an event $C_{t''}$ such that

$P(B_t \cap C_{t''}) > 0$

$P(A_{t'}/B_t \cap C_{t''}) = P(A_{t'}/C_{t''})$

$P(A_{t'}/B_t \cap C_{t''}) \geq P(A_{t'}/B_t)$

The barometer's example might cloud, because of its theoretical obviety, the crucial role played by the conceptual framework in any argument aimed at discriminating between spurious and genuine causes. An example drawn from economics may better illustrate this point. Both Keynes and classical economists would have been ready to admit that an increase of real wages above the full employment level could be considered as a *prima facie* cause of a reduction in employment. However Keynes would have considered such a cause as a spurious one, since both events would have been interpreted as joint effects of a reduction in effective demand. On the contrary, a classical economist, who rejected the principle of effective demand and accepted Say's law, would have considered such a cause as a genuine one.

Suppes approach refers back to the prestigious Humean tradition aiming to extend its validity scope to the analysis of probabilistic phenomena. In addition he goes "beyond Hume" in other two points that have a great epistemological relevance.

First of all, as we have already emphasized, any causal statement is relativized to a theoretical framework. Suppes is here influenced by the contributions of post-positivist philosophers (as Kuhn, Lakatos, Fayerabend) that he integrates in his own version of critical empiricism.

The second one is a stimulating point of view on the *vaexata questio* of "causal production" considered by many authors as an essential characteristic

of any satisfactory causal concept, but considered as a metaphysical heritage, to be thus accurately avoided, by Hume and his followers. Suppes finds the way for analyzing the problem without violating the Humean anti-metaphysical prescriptions. There is no point in denying the existence of "causal mechanisms" that describe and explain how the causal influence is transmitted, or produced, from the cause to the effect, provided that we are aware that these mechanisms may be at variance in different phenomena and may be interpreted in multifarious ways by different theories. In the history of thought we find diverse paradigms of the typical, or "ultimate", causal mechanism. The paradigmatic causal mechanism was founded by Decartes on the impact of physical bodies, while it was founded by Kant on the reciprocal influence of attraction and repulsion forces. Analogously wa may easily detect in economics a traditional contrast between authors who ground the intelligibility of economic phenomena on individual reactions to external stimuli and authors who ground it in an equilibrium configuration of interdependent relations.

Suppes own point of view, consistently with his epistemological pluralism and relativism, rejects the existence of an "ultimate" causal mechanism. Different causal mechanisms may coexist in different empirical and/or theoretical contexts. Moreover, even in the same empirical and theoretical contexts, the paradigmatic causal mechanism of a certain generation of scholars is typically further analyzed and explained by a subsequent generation of scholars in terms of simpler and more basic mechanisms. Suppes is led by these arguments to consider causal mechanisms as "black boxes" which we may analyze without contravening the Humean anti-metaphysical prescriptions[6].

On these premises Suppes was able to work out a very flexible concept of causality that may be applied in different empirical and theoretical contexts. We cannot survey here the interesting articulations, specifications and developments of the concept explored by Suppes and his followers. We will only briefly recall two aspects which are particularly useful for the following analysis.

First of all, Suppes is able to define deterministic causality as a particular

instance of probabilistic causality:

(3) A_t is a sufficient cause of $B_{t'}$ iff
(i) A_t is a *prima facie* cause of $B_{t'}$
(ii) $P(B_{t'}/A_t)=1$

Suppes causality may be thus applied also to deterministic causality.

In addition, Suppes causality applies also whenever probability is not measurable on a cardinal scale. This is particularly important in disciplines like economics where these unhappy circumstances are often true, as was recognized by Keynes and many other economists. As Hicks recently mantained, in economics probabilities are in most cases only ordinable and often not even in a complete way (Hicks, 1979, p. 115). Suppes theory may be easily adapted to these cases translating his quantitative theory in a qualitative one, following the suggestions put forward by Keynes (1921) and developed by Koopman (1940). According to Keynes and Suppes the qualitative notion of probability is essentially comparative and is founded on the following primitive relation:

(4) B given A is at least as probable as D given C:
$(B/A) \geq (D/C)$

As Keynes wittily observed: "no proposition is in itself either probable or improbable, just as no place can be intrinsically distant" (Keynes, 1921, p. 7).

3. Suppes theory of probabilistic causality: open problems and glimpses beyond

As Suppes himself recognized, his theory of probabilistic causality raises more problems than it is able to solve. However we might consider that as the hallmark of a progressive research program. Suppes himself individuates and discusses many of these open questions with a very constructive and anti-

dogmatic attitude. Let us examine a couple of them that are particularly relevant for applications in the field of economics.

First of all, Suppes definition of cause applies only to events. Suppes admits that this assumption is potentially restrictive because "many causes are not conceived as events" (Suppes, 1970, p. 71). This limitation is common to many theories of causality, but is particularly awkward for that of Suppes which is meant to explicate the existing use of the term rather than to stipulate "the right one".

Moreover, the concept of event chosen by Suppes appears, at first sight, very different from the usual one. In ordinary language, by event we mean a change of state rather than a state described in set-theoretic terms. However nothing prevents a definition of a change of state in set-theoretic terms so that in this sense ordinary events are Suppes events, although the opposite is not always true. Moreover in ordinary language events are *actual* events while in Suppes events are *possible* events which may or may not actualize. As we see Suppes meaning includes the ordinary meaning but is much broader and ends by overlapping with philosophers definition of "state of affairs" or "proposition"[7]. Summing up, any object defined in set-theoretic terms may be considered as a Suppes event[8]. This is true in particular for economic variables which are often defined in set-theoretic terms and are however easily definable in such a way. We may conclude that Suppes probabilistic causality may be widely applied in economics.

The second difficulty is more serious. Suppes probabilistic causality in the existing version applies only to instantaneous events. This is a grave limitation for a discipline like economics which often deals with events having a relevant temporal extension ("chunk events" in Suppes language). This is true, in particular, of the stock variables (like wealth, capital, inventories, etc.); as for flow variables (like income, saving, investment, etc.), they are almost never measured in an instant of time. Moreover this problem is particularly serious whenever aggregation is likely to introduce a temporal extension to

the variables involved, and thus especially in macroeconomics.

We may however entertain a reasonable hope that Suppes causality can be extended to chunk events. The theory of probabilistic causality recently worked out by Salmon[9], which is in many respects complementary to that of Suppes, concentrates precisely on the causal analysis of chunk events (called "processes"). An integration of both theories seems not impossible and would be invaluable for working out a theory of probabilistic causality suitable for economic analysis.

The second set of problems is not less serious. The assumption introduced by Suppes, in the spirit of Hume, that the cause has to precede the effect, excludes contemporaneous causation, although we may find many instances of it in ordinary language as well as in various scientific languages. This assumption is thus inconsistent with the explicative rather than stipulative point of view chosen by Suppes theory. This difficulty cannot be overcome inside the current version of Suppes causality because, if we drop the requisite of strict temporal inequality, it is possible to prove that any cause becomes spurious (Suppes, 1970, p. 22). Suppes justifies this assumption appealing, for the physical world, to the principle of "retarded action"; and, for social sciences, to a time-consuming process of communication necessarily mediating individual decisions. Both arguments can be accepted only from a well-defined theoretical and methodological point of view. In social sciences, e.g., methodological individualism and behaviourism are presupposed. I would consider more consistent with the spirit of Suppes contribution a serious attempt to extend his theory in such a way to include also contemporaneous causation. I wish here to suggest the outline of an extension which could achieve this result.

The basic idea is that of distinguishing, following a time-honoured tradition in economic theory, between the "historical" (or "ontological") time t and the "epistemic" time θ (often called by economists "logical")[10]. I mean by historical time the time characterizing natural and social history which is fully independent of any kind of human activity; I mean by epistemic time any irreversible order

of succession, independent of the historical sequence, attributed by the epistemic subject to the elements of a process. A good example of epistemic time is given by the irreversible order of computation implied by a recursive function (this kind of order of succession gives the formal foundation for both the unilateral coupling of Goodwin and the causal relation in Simon and Wold).

I am now in a position to reformulate the first definition of Suppes in the following way

(5) $B_{t\theta}$ is a (potential) *prima facie* cause of $A_{t'\theta'}$ relative to the background information $Z_{t\theta}$, iff

(i) $P(B_{t\theta} \cap Z_{t\theta}) > 0$

(ii) $t < t'$ and/or $\theta < \theta'$

(iii) $P(A_{t'\theta'}/B_{t\theta} \cap Z_{t\theta}) > P(A_{t'\theta'}/Z_{t\theta})$

This definition overcomes the difficulties met by Suppes in defining a concept of contemporaneous causation consistent with his theory. We may define a relation of contemporaneous causation whenever the (5) is specified in the following way: $t=t'$ and $\theta < \theta'$. In other words, the order of succession between cause and effect is in this case merely epistemic and does not imply a temporal succession in the historical sense. An example of contemporaneous causation may be considered the relation between investment and income in the static multiplier of Keynes. In this case we have an epistemic succession grounded on the exogeneity of investment relative to the income-expenditure circuit, but we do not have a succession in historical time.

Suppes causality is a special case of (5) whenever $t < t'$. I will call this kind of causality "sequential" following the terminological suggestion of Hicks (1979). We may distinguish two different kinds of sequential causality: e-sequential whenever $t < t'$ and $\theta < \theta'$, i.e. when the order of succession is both historical and epistemic, and h-sequential when $t < t'$ and $\theta = \theta'$, i.e. when the order of succession is historic but not epistemic. An example of e-sequential causality

may be given by a lagged recursive function (e.g. the dynamic multiplier of Keynes where the autonomous investment, being exogenous, cannot be an effect), while an example of h-sequential causality may be given by a lagged reversible function (e.g. the Keynesian equality between aggregate expenditure and lagged aggregate income; both variables are considered as endogenous: the only reason to individuate a causal order lies in the historical temporal lag).

4. Keynes and Suppes

Keynes often employs in his economic contributions a causal language but he never clarifies there the precise meaning of the causal concepts utilized. However the issue is discussed in a certain detail in the *Treatise on probability* (1921), where he worked out the foundations of his epistemological point of view. We find there a very interesting outline of a theory of probabilistic causality that anticipates, in many respects, the more mature and sophisticated theory of Suppes. The interpreters of Keynesian thought neglected this link[11] also because they could not be acquainted with a fully-fledged theory of probabilistic causality, which is very recent. Keynesian causality has been thus interpreted as a version of deterministic causality close to that of Simon and Wold. The trouble is that Keynes is explicit in judging deterministic causality not very useful, especially for "Moral Sciences"[12]:

"One is led, almost inevitably, to use 'cause' more widely than 'sufficient cause' or than 'necessary cause', because, the necessary causation of particulars by particulars being rarely apparent to us, the strict sense of the term has little utility" (Keynes, 1921, p. 306).

Keynes feels the need of a causality concept much more comprehensive than the traditional one. What is required is a concept of *"probable cause*, where there is no implication of necessity and where the antecedents will sometimes lead to particular consequents and sometimes will not" (*ibidem*, p. 306). He is fully aware of the novelty and difficulties of this task, because "a partial or possible cause involves ideas which are still obscure" (*ibidem*, p. 182). The

main troubles come from the conviction, then universally shared, that physical determinism could not be questioned[13]. Keynes succeedes somehow in getting round the obstacle introducing a crucial distinction between *'causa essendi'*, i.e. ontological cause which in the physical world has to be conceived as deterministic, and *'causa cognoscendi'*, i.e. epistemic cause that may be conceived as probabilistic. The main emphasis is then put on the second meaning because: "we wish to know whether knowledge of one fact throws light *of any kind* upon the likelihood of another. The theory of causality is only important because it is thought that by means of its assumptions light can be thrown by the experience of one phenomenon upon the expectation of another" *(ibidem*, p. 308).

Ontological causality *("causa essendi")* is interpreted as a limit-case of epistemic causality, whenever we have a knowledge of a certain set of phenomena accurate enough to be able to individuate a necessary or sufficient cause. This is possible only if we are able to determine the nomic conditions K, both formal and theoretic, the existential conditions, both general L_t, and hypotetical H_t, which make sufficient or necessary the causal influence of an event on another one.

The nexus between ontologic and epistemic causality is clarified by Keynes through a succession of formal definitions of causality which constitutes a sort of descente from the paradise of certainty to the hell of uncertainty. The starting point is given by a definition of *causa essendi:*

(6) the event A is a sufficient cause of the event B in conditions ℓ, iff
(i) the proposition a describes an event A referred to moments which are all prior to those at which is referred the event B described by proposition b
(ii) $b/ak\ell = 1$ and $b/k\ell \neq 1$

This definition may be easily translated in Suppes language, setting $a=A_t$, $b=B_{t'}$, $kl=K \cap L_t=Z_t$. This is possible because, as we have seen, Suppes events

are strictly analogous to Keynes propositions. The (6) is translated in the following way

(7) A_t is a sufficient cause of $B_{t'}$ relative to $Z_t=K\cap L_t$, iff
(i) $P(A_t \cap Z_t) > 0$ and $t < t'$
(ii) $P(B_{t'}/A_t \cap Z_t) = 1$ and $P(B_{t'}/Z_t) \neq 1$

Notice that A_t is a (potential) *prima facie* cause of $B_{t'}$, because the (ii) implies that $P(B_{t'}/A_t \cap Z_t) > P(B_{t'}/Z_t)$. The (7) of Keynes is thus stricly equivalent to the (3) of Suppes.

Keynes then progressively weakens the definition (7) by relaxing the conditions under which a concept of ontological causality may be defined. An intermediate step is, e.g., the definition of a "possible sufficient cause", when the background information Z_t includes a set H_t of existential hypotheses. The last step of this chain of definitions is that of *causa cognoscendi*

(8) A_t is a *causa cognoscendi* of $B_{t'}$ relative to Z_t iff
(i) $P(A_t \cap Z_t) > 0$
(ii) $P(B_{t'}/A_t \cap Z_t) \neq P(B_{t'}/Z_t)$

We may easily verify that a *causa cognoscendi*, which does not imply a necessary or sufficient nexus between cause and effect, corresponds to a (potential) *prima facie* cause as defined by the (1) of Suppes, apart from the two following differences:

a) the temporal lag is not required. Keynes does not exclude the possibility of an epistemic cause contemporaneous to its effect. No wonder that contemporaneous causation may be found in his economic contributions;

b) the positive statistical relevance of the cause for the effect is not required. In other words a cause might also reduce the probability of the occurrence of the effect (in which case the cause is "negative" or hinibitory)[14].

Keynes stops here in the *Treatise* because the theory of epistemic causality ends up by overlapping with his theory of probability. Still I believe that it is not improper to consider Keynes as a forerunner of the theory of probabilistic causality, especially of the Suppes version.

5. *Granger probabilistic causality*

The causality concept worked out by Granger in the sixties (1963 e 1969), following a suggestion by Wiener (1958), has been and still is at the center of a lively debate on its validity scope and on its implications for economic theory. A few economists and econometricians have even questioned its epistemological legitimacy on the ground that it were inconsistent with an alleged philosophical tradition (see in particular Zellner, 1979). Still Granger causality rapidly became the prevailing notion of causality in economics and econometrics, probably because it was found particularly congenial to the monetarist tendencies which became very popular in the seventies.

Its fortune may be dated back to the publication of an influencial article by Sims (1972) who utilized Granger causality for arguing that the money stock exerts a strong causal influence on nominal income and not *vice versa*. Granger causality rapidly became very popular with "New Classical Economists" (Lucas, Sargent, Barro, etc.) also because it was found very congenial to the rational expectations hypothesis(15). This notion became in addition an important source of inspiration for the New Econometrics founded on time series analysis "without pretending of having too many a priori informations" (Sargent-Sims, 1976 and Sims, 1979). An appraisal of its epistemological legitimacy and of its validity scope is thus very relevant. The observations developed in the preceding paragraphs turn out to be very useful for this task.

Granger develops his conception of causality through a succession of definitions that, not unlike Keynes, paves a downward way toward the hell of uncertainty, justified - in this case - by the exigence of coming up to a definition of causality "operative", i.e. amenable to empirical verification.

Let us assume that Y_n e X_{n+1} are two stocastic variables and Ω_n a complete set of information available at time n and F the function describing the distribution conditional to X.

The starting point is the following definition

Def. 1 Y_n is cause of X_{n+1} iff

(9) $$F(X_{n+1}/\Omega_n) \neq F(X_{n+1}/\Omega_n - Y_n)$$

In other words "for causation to occur, the variable Y_n needs to have some unique information about what value X_{n+1} will take in the immediate future" (Granger, 1980, p. 330). In order to make operative this definition, Granger has to substitute to the complete information set Ω the incomplete information sets J_n (an information set actually available at time n) and J'_n (the information set J_n plus the past and present values of Y_n). We obtain the following definition

Def. 2 Y_n is a *prima facie* cause of X_{n+1} relative to the information set J'_n) iff

(10) $$F(X_{n+1}/J'_n) \neq F(X_{n+1}/J_n)$$

The utilization of incomplete information sets compels the introduction of two qualifications which approach Granger definition to that of Suppes: a) the causal statement has to be relativized to a certain background information; b) Y_n becomes thus only *prima facie* cause because we cannot exclude that, adding new information, it would become spurious.

The definition is not yet operative because an empirical test should up to now refer to population attributes of X_{n+1} that we cannot know. Granger is thus compelled to be content with the first moment of the distribution, introducing the following definition

Def. 3 Y_n is a *prima facie* cause in mean of X_{n+1} relative to the informa-

tion set J'_n iff

(11) $$E(X_{n+1}/J'_n) \neq E(X_{n+1}/J_n)$$

In addition Granger limits himself to point forecasts of X_{n+1} using a least squares criterion. Let $\sigma^2(X/J_n)$ be the variance of the one step forecast error of X_{n+1} given J_n, we may eventually express an operative definition of Granger causality

Def. 4 Y_n is a *prima facie* cause in mean of X_{n+1} relative to the information set J'_n iff

(12) $$\sigma^2(X_{n+1}/J'_n) < \sigma^2(X_{n+1}/J_n)$$

In other words, the knowledge of Y_n increases one's ability to forecast X_{n+1} in a least squares sense, because it reduces the variance of our forecast errors. Since much of current economic and econometric practice is prediction-oriented, we may well understand why this definition, although very restrictive, has appealed to many. However, the definition actually tested is further restricted to linear predictors (Granger, 1969, p. 429; and 1980, p. 338), owing to the limitations of the available modelling and forecasting techniques:

Def. 5 Y_n is a linear *prima facie* cause in mean of X_{n+1} relative to the information set J'_n iff the (12) is applied to a class of linear predictors.

From now on I will mean by Granger causality the concept stipulated in this last definition.

Before discussing the validity scope of this concept, we have to recall that its operational implementation is subject to further limitations. The principal ones are made explicit by Granger himself by the following axioms:

Axiom A. "The past and present may cause the future, but the future cannot cause the past" (Granger, 1980, p. 330). This axiom excludes not only backward causation, whose relevance is questionable, but also "contemporaneous causation" which -as we have seen- is considered important by many economists.

Axiom B. The information sets contain no redundant information (*idibem*, p. 330). This axiom is much more restrictive than it may appear at first. Redundant information could ingenerate the wrong conviction that a certain *prima facie* cause is spurious. This difficulty is particularly serious with economics, whose time series often follow a very similar temporal pattern.

Axiom C. All causal relationships remain constant in direction through time (*ibidem*, p. 335). This axiom has been considered very stringent by a few critics (see, e.g., Zellner, 1982, p. 314). However Granger is right in pointing out that this assumption, though literally not true, is usual in causal inference and, indeed, in scientific inference. Much more disturbingly restrictive should be considered the related hypotesis, routinely accepted in testing procedures of Granger causality, that the series are jointly covariance stationary. This assumption, according to Granger, is not strictly necessary for the definition of causality but is required for practical implementation. He admits that economic time series are often nonstationary, but he believes that they can be made stationary by transformations such as those suggested by Box-Cox and Box-Jenkins. Unfortunately it may be shown that these transformations do not preserve the causal properties of the original time series (cfr. Conway-Swamy-Yanagida, 1983, p. 17-23).

In addition, we have to emphasize that, as underlined by Granger himself (1980), his definition of causality does not apply to single events, to deterministic processes, as well as to data non measurable on a cardinal scale.

6. Granger and Suppes

As we have seen, the applicability scope of Granger causality is much more narrow than that of Suppes causality. We may further clarify the issue translating in the Suppes language the definition 2 of Granger, which is the

most general definition that postulates incomplete information as in Suppes. Let assume that $A_{t'} = X_{n+1}$, $B_t = Y_n$, $Z_t = J_n$, $B_t \cap Z_t = J'_n$, and that both $A_{t'}$ and B_t occurred. Def. 2 of Granger may be thus expressed in the following way:

(13) B_t is a *prima facie* Granger cause of $A_{t'}$ relative to background information Z_t iff

(i) $A_{t'}$ and B_t occur and $t < t'$

(ii) $F(A_{t'}/B_t \cap Z_t) \neq F(A_{t'}/Z_t)$.

As we may easily verify comparing the (13) with the (1) Granger causality appears as a particular case of Suppes causality[16]. This is enough in order to confer to Granger causality a *prima facie* philosophic legitimacy wrongly denied by Zellner. Moreover, it looks as if it were possible that the causality notion adopted by Keynes and that adopted by the New Classical Economists, though uncompromising anti-Keynesians, belong to the same philosophic family.

However, the formal analogy clouds a profound difference. Background information encompasses in both Keynes and Suppes a theoretical framework, while in Granger includes only the past and present values of the relevant stochastic variables. The other peculiarities of Granger causality, as the exclusive reference to single events actually happened and thus not to types of events and to dispositional magnitudes, all descend from this inductivist point of view. The supporters of Granger causality see in that the reason for vindicating its superiority over competing notions of causality. In their opinion, Granger causality is the only notion of causality actually operative, in the sense that the results of empirical tests are "non-conditional", i.e. independent of a priori theoretical assumptions. This alleged superiority is argued in particular vis-à-vis Goodwin-Simon-Wold causality, which was, and still is, the main existing alternative for economic analysis. It is shown that, on the formal point of view, these two notions are strictly analogous and that the only relevant

difference regards the explicit conditionalization by Goodwin-Simon-Wald causality to a theoretical framework. It is moreover admitted that the applicability scope is broader in this second case. Were we able to prove that the unconditionality claim is wrong, the superiority claim would be in general denied, if not reversed. This is what we are going to show.

Many empirical tests of Granger causality have been devised with different advantages and disadvantages. They have however all in common a two-stage procedure of implementation. In the first stage a few statistical tests are applied to empirical data; in the second stage the results of these tests are interpreted. In the first stage the theoretical hypotheses are not clearly defined. It could be objected that any procedure of selection and manipulation of data already presupposes a theoretical point of view, even if only implicit[17]. Whatever we think of this objection, in the second stage serious difficulties emerge that we believe insuperable. The crucial problem is that of discriminating between genuine and spurious causes. This cannot be done without an *explicit* intervention of theoretical hypotheses. Granger, Sims and the other supporters of Granger causality believe that they are able to come round this obstacle. They discuss a list of circumstances under which a *prima facie* cause is likely to be spurious in order to prove that all these circumstances are extremely unlikely in the case of Granger causality. Unfortunately this strategy fails.

In order to exclude, e.g., that we can find a third variable that would make spurious a *prima facie* cause, it is suggested the repetition of certain empirical tests to all the variables that might have this effect. This procedure is clearly unacceptable, unless we set a sufficient number of a priori theoretical assumptions on the behaviour of the economic system. Otherwise the list of third variables which could induce spuriousness would be virtually infinite.

More in general, we may observe that we cannot demonstrate that a list of circumstances which might induce spuriosness is really exhaustive. An a priori discussion on the likelyhood of certain circumstances spuriosness-inducing cannot increase substantially our confidence on the "genuinity" of a certain

prima facie cause, unless we explicit our theoretical background. Even Granger causality is thus conditional to a certain theoretical conceptual framework. The only real difference on this respect is that the theoretical hypotheses are made explicit in Goodwin, Simon and Wold while they remain implicit in Granger and Sims. The charge of presumption against Simon and Wold may be thus reversed against Granger and Sims. What is really beyond our capabilities is that of asserting the truth of a causal statement "pretending" that it is "unconditional" to a given theoretical framework.

Granger and Sims seem unaware of the well-know limits of the inductive methods, that have been clarified by the prestigious philosophical tradition going from Hume to Popper and beyond. They apparently accept one or more of the following mistaken axioms:

- measurement is possible without theory,
- correlation implies causation,
- *post hoc ergo propter hoc.*

Each of these theses is sometimes provocatively entertained by the supporters of Granger causality[18] perhaps to boast the novelty of their conception, as if the new techniques of time series were by themselves able to overcome the traditional methodological prescriptions. So doing they slip in the pit-falls of "operationism" and of "inductivism" since long rejected by philosophy of science.

However, there is a second line of defense for Granger causality which is less pretentious but more convincing. Granger causality is considered just particularly relevant for certain specific scientific aims. We recall in particular the following claims (see, e.g., Sargent, 1977, Sims 1972 and 1977):

a) Granger causality is a necessary and sufficient condition for exogeneity which is a necessary condition for efficient estimation;

b) Granger causality is a necessary and sufficient condition for optimal forecasts;

c) Granger causality is a necessary condition, even if not sufficient, for economic policy (forecast and control).

Unfortunately, even these claims are exagerated. Granger causality is a necessary but not sufficient condition for predicting the outcomes of processes not influenced by policy and, in any case, structurally stable, but it is neither necessary nor sufficient condition for correct estimation, nor for prediction and control of processes influenced by policy interventions or however structurally unstable (Engle, Hendry, Richard, 1983).

We may thus conclude that Granger causality is not without relevance for a few well defined and circumscribed scientific aims. The claim of its general superiority over alternative notions of causality, and in particular that of Goodwin-Simon-Wold, is on the contrary fully groundless.

7. Conclusions

The notion of probabilistic causality in the version of Suppes has been precious for clarifying two notions of causality particularly relevant for economic analysis: that of Keynes and that of Granger.

We could ascertain that Keynes causality is probabilistic and anticipates in many respects the more recent and mature theory of Suppes.

Granger notion, that is today very popular particularly among anti-Keynesian economists and econometricians, can be interpreted in its turn as a particular version of Suppes causality. However we could ascertain that, behind the formal analogies, profound philosophical divergences between Keynes and Granger are detectable. While Keynes, as well as the supporters of the main alternative conception (Goodwin-Simon-Wold), insists on the necessary relativization of any causal statement to a well defined theoretical background, the supporters of Granger causality claim the superiority of their notion precisely because of its alleged independence of theoretical hypotheses. This presumption proves completely groundless and with it that of its general superiority over alternative notions, also if this does not exclude its utility for well defined and circumscribed scientific aims. In particular we have found that it is a necessary, though not sufficient, condition for efficient predictions of the outcomes of

processes not influenced by policy interventions or in any case structurally stable.

The preceding considerations are not without implications for the lively debate between New Classical Economists and Keynesian economists. All the superiority claims founded on the results of Granger causality tests have to be considered as ungranted because they depend on a priori theoretical hypotheses that are not explicitely discussed in these contributions.

NOTES

(1) The importance of this contribution for the modern development of causal analysis in economics is pointed out by Velupillai, 1982, p. 79.

(2) This is explicitly recognized by Simon himself (1953, fn. 5). We should recall that a similar notion of causality has been indipendently worked out in the same years by Wold (1949, 1954).

(3) See, e.g., Pasinetti, 1974.

(4) On the concept of explication see, e.g., Carnap, 1950, 1st chapter.

(5) Cfr. e.g. Suppes, 1970.

(6) Bunge (1982) and other authors criticized Suppes theory of causality because in their opinion causal production is there completely neglected. This criticism seems to me notwell founded.

(7) See on the same line Spohn, 1983. The same opinion has been recently expressed by Suppes himself (1981, p. 25).

(8) The conviction that the traditional meaning of event, defined as a change of state, is too restrictive for most uses of the term, became recently widespread among philosophers and methodologists. See on this, e.g. Kim, 1973.

(9) Salmon developed since early sixties, following Reichenbach, a theory of probabilistic causality of great interest. An excellent synthesis has been recently given by Salmon himself in an important monograph (1984).

(10) This distinction appears, though with somewhat different meanings, in authors as J. Robinson, Hicks, Shackle, Georgescu-Roegen.

(11) A relevant exception is the excellent essay by Carabelli, 1984, where Keynesian causality is correctly interpreted as probabilistic causality. However the author does not try to formalize the notion, nor to compare it with alternative definitions.

(12) I recall that Keynes classifies economics among Moral Sciences, whose method is contrasted to that of Natural Sciences. See e.g., Keynes, CW XIV, 300.

(13) As is rightly observed by Weatheford, 1982, this depends very much on the fact that Keynes was writing in that happy epoch that preceded the quantum mechanics revolution (p. 106).

(14) This possibility is admitted by Suppes himself though it is not made explicit in the definitions here recalled.

(15) Lucas and Sargent explain why "Granger causality is of natural interest for scholars of rational expectations" in the Introduction to Lucas-Sargent, 1981, pp. xxii-xxiv.

(16) A thesis in many respects analogous is maintained by Spohn, 1983. He rightly emphasizes, moreover, a few notational problems of Granger's definitions. However Spohn's analysis does not perceive the crucial point: the profoundly different role that background information plays in the causal theory of the two authors.

(17) See, e.g., Blaug, 1980, p. 14.

(18) An example is given by the following passage of Sims: "The method of identifying causal direction employed here does rest on a sophisticated version of the *post hoc ergo propter hoc* principle" (Sims, 1972, p. 543).

REFERENCES

Blaug, M., 1980, *The Methodology of Economics*, Cambridge Un. Press, Cambridge.

Bunge, M., 1982, The revival of causality, in G. FlØistad (ed.), *Contemporary Philosophy*, Vol. 2, pp. 133-155.

Carabelli, A., 1984, Causa, Caso e Possibilità, in J.M. Keynes, in Lunghini et al., 1984.

Carnap, R., 1950, *Logical Foundations of Probability*, Chicago.

Engle, R.F., Hendry, D.F., Richard, J.F., 1983, Exogeneity, *Econometrica*, vol. 51, n. 2.

Galavotti, M.C., Gambetta, G., cur., 1983, *Causalità e modelli probabilistici*, CLUEB, Bologna.

Geweke, J., 1984, Inference and causality in economic time series models, in Griliches-Intriligator (eds.), *Handbook of Econometrics*, vol. II, 1984, pp. 1101-1144.

Good, I.J., 1961/62, A causal calculus I-II, *British Journal for the Philosophy of Science*, 11, p. 305-318; 12, p. 43-51.

Goodwin, R.M., 1947, Dynamical Coupling with Especial Reference to Markets Having Production Lags, *Econometrica*, Vol. 5, pp. 181-204.

Granger C.W.J., 1963, Economic Processes Involving Feedback, *Information and Control*, 6, 28-48.

Granger, C.W.J., 1969, Investigating Causal Relations by Econometric Models and Cross-spectral Methods, *Econometrica*, 37, p. 424-438.

Granger, C.W.J., 1980, Testing for causality: A personal viewpoint, *Journal of Economic Dynamics and Control*, 2, p. 303-328.

Hicks, J., 1979, *Causality in Economics*, Blackwell, Oxford.

Keynes, J.M., 1921, A *treatise on probability*, Macmillan, New York.

Kim, J., 1973, Causation, Nomic Subsumption and the Concept of Event, *Journal of Philosophy*, Vol. LXX, n. 8.

Kolmogorov, A.N., 1933, *Grundbegriffe der Wahrscheinlichkettsrechnung*, Springer, Berlin; trad. ing. (1956), *Foundations of the theory of probability*, Chelsea, New York.

Koopman, B., 1940, The Basis of Probability, *Bulletin of American Mathematical Society*, vol. 46.

Lucas, R.E., Sargent, J.T., eds., 1981, *Rational expectations and Econometric practice*, Allen and Unwin, Londra.

Lunghini, G. *et al.*, 1984, La scienza impropria, *Metamorfosi*, 8, Angeli, Milano.

Pasinetti, G.L., 1974, *Growth and Income Distribution. Essays in Economic Theory*, Cambridge University Press, Cambridge.

Reichenbach, H., 1956, *The Direction of Time*, University of California Press, Berkeley.

Salmon, W.C., 1984, *Scientific Explanation and the Causal Structure of the World*, Princeton Un. Press, Princeton, N.J..

Sargent, T.J., Sims, C.A., 1977, Business cycle modelling without pretending to have much a priori economic theory, in C.A. Sims, ed., *New Methods in Business Cycle Research*, Federal Reserve Bank of Minneapolis.

Simon, H.A., 1952, On the definition of the Causal Relation, *The Journal of Philosophy*, 49, pp. 517-528.

Simon, H.A., 1953, Causal ordering and identifiability, in Hood-Koopmans (eds.), *Studies in Econometric Methods*, N.Y., J. Wiley, pp. 49-74.

Simon, H.A., 1954, Spurious Correlation: a Causal Interpretation, *Journal of American Statistical Association*, pp. 467-479.

Sims, C.A., 1972, Money, Income and Causality, *American Economic Review*, 62, pp. 540-552.

Sims, C.A., 1977, Exogeneity and Causal Ordering in Macroeconomic Models, in Sims, ed., op. cit.

Sims, C.A., 1979, Macroeconomics and reality, *Econometrica*, 48, pp. 1-48.

Spohn, W., 1983, Probabilistic causality: from Hume via Suppes to Granger, in Galavotti-Gambetta, 1983.

Suppe, F. (ed.), 1977, *The Structure of Scientific Theories*, Un. of Illinois Press, Urbana, Ill.

Suppes, P., 1970, *A probabilistic theory of causality*, North-Holland, Amsterdam.

Suppes, P., 1981, *La logica del probabile*, trad. it., CLUEB, Bologna, 1984.

Velupillai, K., 1982, Linear and Nonlinear Dynamics in Economics: The Contributions of Richard Goodwin, *Economic Notes*, n. 3.

Wiener, N., 1958, The Theory of prediction, in Beckman, ed., *Modern mathematics for engineers*, Series 1, ch. 8, McGraw-Hill, New York.

Wold, H.O., 1949, Statistical Estimation of Economic Relationships, *Econometrica*, Vol. 17, Suppl. (July), 1-21.

Wold, H.O., 1954, Causality and Econometrics, *Econometrica*, 22, 162-177.

Zellner, A., 1979, Causality and Econometrics, in Brunner-Meltzer, eds., *Rochester Conference Series on Public Policy*, 10, North Holland, Amsterdam.

Zellner, A., 1982, Comment to J. Geweke, Measurement of Linear Dependence and Feedback Between Multiple Time series, *Journal of the American Statistical Association*, 77, 313-314.

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