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GRANGER-CAUSALITY AND POLICY INEFFECTIVENESS: A REJOINDER

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ABSTRACT

In an earlier paper "Granger-causality and Policy Effectiveness," Economica [1984], I showed that for a policy instrument x to Granger-cause some target variable y is not necessary for x to be useful in controlling y. (The argument that it is not sufficient was already familiar, e.g. from the work of Sargent). Using a linear rational expectations model I showed that x would fail to Granger-cause y (while y did, in some cases, Granger-cause x) if x were set by a variety of optimal, time-consistent or ad hoc policy feedback rules. Yet in all the examples, x was an effective policy instrument.

In response to some comments by Professor Granger, I now show that my earlier results are unaffected when the following 3 concessions to "realism" are made:

1. Controllers do not have perfect control of the instruments (this was already allowed for in my earlier paper).
2. Governments may use a different information set to determine instruments than that used by the public.
3. The controller may not have perfect specifications and estimates of models of the economy.

The analysis confirms that Granger-causality tests are uninformative about the presence, absence, degree or kind of policy (in)effectiveness.

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In my (1984) paper, "Granger-causality and Policy Effectiveness," I argued that "Granger-causality" is unnecessary and insufficient for policy effectiveness. Since it was already well-established that the fact that a policy instrument x Granger-caused some economic variable y, did not imply that x could be used to control or influence y (see e.g. Sargent [1976]), my paper focused on the case where x does not Granger-cause y yet can be used to influence or control y. I established this in the context of linear rational expectations models with known, constant coefficients, by demonstrating that x would fail to Granger-cause y (while y did, in some cases Granger-cause x) if x were set by a variety of optimal, time-consistent or ad-hoc (stochastic or non-stochastic) linear feedback rules. Yet in all the examples chosen, x was an effective policy instrument: different values of x_t (different realizations of x_t) were <u>cet par.</u> associated with different values of y_{t+i} (different realizations of y_{t+i}) $i \geq 0$, and different (linear feedback) rules governing x did generate different conditional and/or unconditional distribution functions for y.

In his response to my paper professor Granger (1986) does not dispute that the examples I gave were correct. Rather than attacking the logic of my argument, its relevance is denied:

> "However, the framework considered by Buiter is academic, sterile and quite unrealistic and is thus a very special situation. To make it more realistic three further items need consideration:
>
> (i) controllers do not have perfect control of the instruments,
> (ii) governments may use a different information set I_t to determine instruments than that used by the public, Ω_t, to form expectations and to anticipate instrumental variables, and
> (iii) economy controllers in practice do not have perfectly formed specifications and estimates

> of models of the economy ..., they do not have a consistent or clear-cut value for the target or desired values for endogenous variables and they do not have a specific cost function, ... They may thus appear to be behaving irrationally or sub-optimally by a public using a different model, a different information set and an assumed set of targets and cost functions." (Granger [1986], pp. 7-8).

I shall show that Professor Granger's points (i), (ii) and (iii) are irrelevant for the issue of the informativeness concerning policy effectiveness of Granger-causality tests. This will be done using his own suggested modifications of my formal framework.

In my (1984) paper, the model of the economy was that given in (1).

$$(1) \qquad Y_t = AY_{t-1} + B_1E(Y_{t+1}|\Omega_{t-1}) + B_2E(Y_t|\Omega_{t-1}) + Cx_t + b_t + u_t$$

Y_t is a vector of state, target or endogenous variables, x_t a vector of instruments, b_t a vector of exogenous variables and u_t a white noise disturbance vector assumed to be orthogonal both to the private sector's information set Ω_{t-1} and to the public sector's information set I_{t-1}. E is the mathematical expectation operator.

For simplicity and notational economy, and because none of Professor Granger's objections to my paper are affected by it, I shall in this rejoinder purge the model of expectations and exogenous variables, i.e. $B_1 = B_2 = b_t = 0$. Therefore, the model of the economy (Professor Granger's "plant equation") is

$$(2) \qquad Y_t = AY_{t-1} + Cx_t + u_t$$

Inside Lags and Outside Lags

Professor Granger objects to the notion of an instantaneous, immediate or contemporaneous effect of x on Y.

> "[Because of the timing question, the usual notion of x_t causing y_t, with lags inherent in the definition of causation, will here be denoted as x_{t-1} causing y_t]" (Granger [1986], p. 3).

I consider it unnecessarily restrictive to rule out instantaneous effects from x_t on y_t, since automatic (fiscal) stabilizers are assumed to work in precisely that manner, but in the interest of maximizing the common ground I would be quite happy to grant Professor Granger a lag, in which case equation (2) becomes:

$$(2') \qquad Y_t = AY_{t-1} + Bx_{t-1} + u_t$$

Professor Granger's arguments about timing appear, however, to confuse what in the economic policy literature have long been called "inside lags" and "outside lags" in the policy process. The inside lag is the lag between the period, t say, in which an instrument value x_t is realized and the first period, $t - \tau_i$, $\tau_i \geq 0$ say, in which the full information $I_{t-\tau_i}$ was available on which the controller based his or her decision concerning x_t. The inside lag reflects the many sources of delay in the policy design and implementation process.

The outside lag is the minimal lag, $\tau_0 \geq 0$ say, between the period in which a value for the control is realized, $t - \tau_0$, say, and the period in which it has its first effect on the endogenous variable, t. In equation (2) the outside lag is 0, in equation (2') it is 1. The inside lag hasn't been specified yet. In equations (3a, b) below it is 1. A non-economic example may help. Let t be the period in which the French government explodes an H-bomb; $t-i$, $i \geq 0$ the period in which the decision was taken to explode that bomb in period t, or the period with the most recent information that was still reflected in the decision to stage the explosion at t; and $t+j$, $j \geq 0$ the first period in which the fallout reaches Australia. Here j is the outside lag and i the inside lag.

In his rejection of instantaneous causation, Professor Granger seems to argue for a minimal outside lag of one period. He also appears to argue in favor of (at least) a one period inside lag, since, using his notation, x_t is specified as:

$$\text{(3a)} \qquad x_t = w_{t-1} + e_t$$

where e_t is white noise with respect to the information set I_{t-1}. e_t is a policy implementation error.

$$\text{(3b)} \qquad w_{t-1} = E\,[x_t \mid I_{t-1}]$$

The final equation Professor Granger appears to favor does, however, not appear to have any outside lag. Since my results concerning Granger-causality and policy effectiveness hold for any inside and/or outside lags, I am happy to follow Professor Granger's lead here and to use equations (2) and (3a, b) rather than (2') and (3a, b).

Granger-causality and Policy Effectiveness in a "Realistic" Setting

Private agents in period t have the information set Ω_t which contains y_{t-i} and x_{t-i}, $i \geq 0$. The government in period t has the information set I_t, which contains y_{t-i}, x_{t-i} and z_{t-i}, $i \geq 0$. z_t is the vector of extra information available to the government. Let $Y_t' \equiv (y_t', z_t')$. Y_t is governed by equation (2) or, partitioning all vectors and matrices conformably,

$$(4) \qquad \begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} C_1 \\ C_2 \end{bmatrix} x_t + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix}$$

$u_t' = [u_{1t}' \; u_{2t}']$ is a white noise disturbance vector. It is orthogonal to Ω_{t-1} and therefore also to I_{t-1}.

The policy rule is given by (3a,b), where e_t is orthogonal to I_{t-1} (but not necessarily to Ω_{t-1}).

Furthermore, using my own notation,

$$(5) \qquad w_{t-1} = g(I_{t-1}, t-1) + \varepsilon_{t-1}'$$

ε_{t-1}' is orthogonal to I_{t-1} (but not necessarily to Ω_{t-1}). It reflects "uncertain and changing policy objectives."

Equation (5) can also be rewritten as in equation (7) of Granger (1986).

$$(6a) \qquad w_{t-1} = f(\Omega_{t-1}, t-1) + \varepsilon_{t-1}$$

$$(6b) \qquad \varepsilon_{t-1} = \varepsilon_{t-1}' + \varepsilon_{t-1}''$$

where

$$(6c) \qquad \varepsilon''_{t-1} = g(I_{t-1}, t-1) - f(\Omega_{t-1}, t-1)$$

ε''_{t-1} reflects the extra information available to the government. It is orthogonal to I_{t-1} but not necessarily to Ω_{t-1}.

It's obviously true that if the public estimates an equation such as (4) from just the y_t and w_t or x_t, then the instrument vector generated by (3a,b) and (5) or by (3a,b) and (6a,b,c) will contain information about the z_t that are unobserved by the public. Granger causality tests involving just y and x may therefore incorrectly attribute the incremental predictive power over y of the omitted variables z to the x variables. The term "incorrectly" in the previous sentence means incorrectly as Granger-causality tests, that is incorrectly as tests of "incremental predictive content" [Schwert (1979)]. Even if this familiar omitted variables problem is absent, correctly conducted Granger-causality tests will not be informative about the government's scope for influencing or controlling the y_t (or Y_t) through the x_t.

This becomes clear once we do the Granger-causality test correctly for Y_t and x_t. For simplicity, let the $g(I_{t-1}, t-1)$ function in (5) be a time-invariant linear function G of Y_{t-1}, i.e.

$$(7) \qquad w_{t-1} = GY_{t-1} + \varepsilon'_{t-1}$$

where G is a constant matrix and ε'_{t-1} is orthogonal to $\{Y_{t-i}, i \geq 1\}$. The relevant system of equations for informed Granger-causality testing is

(8) $$Y_t = [A + CG]Y_{t-1} + C[\varepsilon'_{t-1} + e_t] + u_t$$

(9) $$x_t = GY_{t-1} + \varepsilon'_{t-1} + e_t$$

By assumption, u_t, ε'_{t-1} and e_t are all orthogonal to I_{t-1}, i.e. orthogonal to Y_{t-1}. Simple inspection will confirm the following: (i) controllers do not have perfect control of the instruments (as evidenced by the presence in (8) and (9) of e_t); (ii) governments may use a different information set from that used by the public [x_t may feed back from z_{t-1} which is not contained in Ω_{t-1}) and (iii) governments may have uncertain and changing policy objectives (ε'_{t-1} is present in (8) and (9)). Nevertheless, x will fail to Granger-cause Y while, unless C = 0, x does influence Y and can be used to control Y. In addition, in this example, Y will Granger-cause x. Paraphrasing the introduction to my (1984) paper, equations (8) and (9) demonstrate that, if the value of a vector of endogenous variables is a function of current, past, and/or expected future values of a vector of policy instruments, and if the instruments are functions of current and/or lagged values of the endogenous variables (plus white noise), then the instruments won't Granger-cause the endogenous variables even though changing the policy rule may alter the dependence of the endogenous variables on their own lagged values and on the exogenous variables.

Conclusions

There are important practical issues and even some moderately deep conceptual issues involved in first defining and then measuring policy effectiveness. Even in models without forward-looking rational expectations, policy effectiveness is a multi-dimensional concept. First one should specify the precise nature of the change in the policy rule that is being considered (whether it is a change in the known value of a coefficient in a policy feedback rule; a change in the variance of the disturbance term in the policy rule, etc.). Second, one should determine the exact nature of the changes in the joint distribution functions of the endogenous or target variables that result from the policy rule change. Does the change in the policy rule alter these conditional or unconditional means of these variables, their conditional or unconditional variances and covariances, etc.?

In models with forward-looking rational expectations, the counterfactual to the policy experiment must be specified carefully. "Effective relative to what?" is not answered very easily. In the most general case the counterfactual is to be thought of along the lines of the following thought experiment. Consider two economic systems, identical in all respects except for the policy rule. This policy rule may be open-loop and non-stochastic, open-loop stochastic, closed loop with only additive uncertainty or closed-loop with more general uncertainty such as random multiplicative parameters. Economic agents are endowed with more or less accurate subjective priors over current and future policy behavior, which they may update sequentially, say in Bayerian fashion, as new realizations of the policy variables are observed. "Changes in policy" here means different drawings from the "objective" policy instrument rule distribution function. Policy effectiveness is measured by differences in the realizations or distribution functions of the endogenous target variables when different drawings are made from the policy instrument rule distribution function.

This is a-historical, "alternative universes" counterfactual is not in fact different from the "historical counter-factual" which economists often appear to have in mind when discussing economic policy. The historical counterfactual asks about the consequence of changing a policy rule at a point in time rather than about differences between target variable behavior when there are differences between the policy rules during one or more periods in two otherwise identical universes. To analyse the consequences of a change in the policy rule at t' we must known when and to what extent this change was anticipated by private and government agents, the degree to which it was perceived as permanent or transitory and the degree of confidence with which these expectations were held. Providing all this information amounts to constructing the a-historical counterfactual.

This rejoinder has amplified what I established in my 1984 paper: Granger-causality tests are not in any way useful or relevant for establishing the presence or absence of policy effectiveness, even when all the technical problems associated with conducting these tests properly are absent or resolved (including any missing variables problems). For instance, if monetary and fiscal variables do not Granger-cause some real or nominal variables (such as GDP, the inflation rate or the exchange rate) this has no implications as regards the ability of the monetary and fiscal authorities to use these monetary and fiscal variables to control the economy. If the exchange rate does not Granger-cause the price level this does not mean that a devaluation won't raise the price level.

Ironically, a well-known paper by Professor Granger [1980] contains in consecutive paragraphs two statements, the first of which reflects the same confusion that prompted his response to my paper, while the second is correct.

The (incorrect) first statement occurs after a brief discussion of exogeneity.

> "One can argue that a government controlled interest rate is in fact partly determined by previous movements elsewhere in the economy, and so is not strictly exogenous. The true exogenous part of such a variable is that which cannot be forecast from other variables and its own past, *and it follows that it is only this part that has any policy impact*." (Granger [1980], p. 350, italics added).

The non-sequitur in the last sentence parallels Professor Granger's misunderstanding of the relation between testing for Granger-causality and for policy effectiveness.

For a policy variable or instrument to have impact or be effective, it is neither necessary nor sufficient that a change in the rule governing the instrument makes the actual behavior of the target variables different from what was expected. Rather, both actual and expected behavior should be different from what they would have been absent the change in the rule. It is perfectly sensible, e.g. to analyze policy (in)effectiveness issues using a deterministic model. Granger-causality tests of course only make sense in non-deterministic models.

The (correct) second statement occurs immediately following the first.

> "It is also worth pointing out that controllability is a much deeper property than causality, in my opinion, although some writers have confused the two concepts. If Y causes X, it does not necessarily mean that Y can be used to control X." (Granger, 1980, p.351).

Both my paper and this rejoinder are no more than amplifications of this statement.

References

Buiter, Willem H. (1984). "Granger-causality and Policy Effectiveness," Economica, 51, pp. 151-162.

Granger, C. W. J. (1980). "Testing for Causality: A Personal Viewpoint," Journal of Economic Dynamics and Control, 2, pp. 329-352.

__________, (1986). "Causality Testing of Control Variables -- A Response to Buiter," Unpublished, May.

Sargent, T. J. (1976). "A Classical Macroeconometric Model for the United States," Journal of Political Economy, 84, pp. 207-237.

Schwert, G. W. (1979). "Tests of Causality. The Message in the Innovations," in K. Brunner and A. H. Weltzer (eds.), Three Aspects of Policy and Policy Making: Knowledge, Data and Institutions. Amsterdam: North-Holland, pp. 55-96.