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A NOTE ON THE NERLOVE MODEL OF AGRICULTURAL SUPPLY RESPONSE*

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1. INTRODUCTION

Judged by the number of studies which follow a particular approach more or less closely, Nerlove's famous formulation of agricultural supply response is certainly one of the most successful econometric models introduced into the literature. The surveys of Askari and Cummings [1976, 1977] provide clear evidence. Even though they are restricted to the English literature, they contain the results of well over one hundred empirical studies in the Nerlovian tradition.

In examining Askari and Cummings' very helpful summary tables, one is unavoidably struck by some extreme discrepancies in long-run supply elasticities found by different researchers for the same crops and regions and almost identical observation periods. While such discrepancies may be due to different definitions of the key variables or to certain modifications of the basic model and thus to aspects which are extensively discussed by Askari and Cummings, they might alternatively reflect a serious collinearity problem that appears to be built into the Nerlove model and which may not be resolvable. It is the purpose of this note to draw attention to this apparently largely overlooked problem, briefly discuss its consequences and provide another empirical example in which the suggested collinearity may be responsible for obviously unreliable supply elasticity estimates.

2. THE NERLOVE MODEL

In its simplest version Nerlove's model consists of the three equations

$$A_t^* = \alpha_0 + \alpha_1 P_t^* + u_t \tag{1}$$

$$P_t^* = P_{t-1}^* + \beta(P_{t-1} - P_{t-1}^*) \tag{2}$$

$$A_t = A_{t-1} + \gamma(A_t^* - A_{t-1}) \tag{3}$$

where A_t and A_t^* are actual and desired area under cultivation (or sometimes output or yield) at time t, P_t and P_t^* are actual and expected price at time t, and β and γ are the expectation and adjustment coefficients, respectively. Elimination of the unobservable variables A^* and P^* leads immediately to the reduced form

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$$A_t = b_0 + b_1P_{t-1} + b_2A_{t-1} + b_3A_{t-2} + v_t \tag{4}$$

with

$$b_0 = \alpha_0\beta\gamma,\ b_1 = \alpha_1\beta\gamma,\ b_2 = (1-\beta)+(1-\gamma),\ b_3 = -(1-\beta)(1-\gamma)$$

and

$$v_t = \gamma(u_t - (1-\beta)u_{t-1})$$

from which the key parameter α_1 may be retrieved by means of the identity $\alpha_1 = b_1/(1-b_2-b_3)$. The long-run price elasticity ε is then usually calculated as

$$\varepsilon = \alpha_1\frac{\bar{P}}{\bar{A}} = \frac{b_1}{1-b_2-b_3}\frac{\bar{P}}{\bar{A}} \tag{5}$$

where $\bar{P}$ and $\bar{A}$ could represent, following, e.g., Nerlove and Addison [1958], some historical mean of prices and acreage under cultivation, respectively.

Neither the economic rationale of the basic model (1) through (3) nor the estimation problems connected with the appearance of lagged dependent variables and the likely serial correlation of the disturbance term in (4) is at issue here. In fact, in what follows any such serial correlation among the disturbances will be assumed away in order to isolate more clearly the effects of the alleged collinearity problem. This collinearity arises because of the simultaneous appearance of the variables P_{t-1} and A_{t-1} on the RHS of (4). In many practical applications these two variables will be related by a demand function lagged one period,

$$P_{t-1} = \delta_0 + \delta_1A_{t-1} + w_{t-1} \tag{6}$$

where w_{t-1} is some random term, δ_1 is negative and δ_0 represents other demand determinants such as population or income.[2] Indeed, unless the market under consideration is tightly controlled by the government or dominated by a preponderant supraregional or world market, one would expect actual output in $t-1$ to follow closely actual acreage A_{t-1} and thus a negative correlation to exist between A_{t-1} and P_{t-1}.

As is well known any collinearity among explanatory variables such as the one presumed between P_{t-1} and A_{t-1} is likely to produce errors in the estimation of the parameters b_i including those which are required to calculate the long-run elasticity. Without further knowledge it is, of course, impossible to be more specific about the effects of such errors on the resulting elasticity estimate other than that its reliability suffers. If we assume, however, that the random term w_{t-1} in the hidden demand function (6) is in general independent of the acreage decisions in both $t-1$ and $t-2$, it is easy to show in a straightforward application of a simple case treated in Johnston [1972, pp. 161 f.] that in view of the assumed

[2] In order not to distract from the main line of the argument we disregard the possibility of δ_0 being dependent on p_{t-1} and A_{t-1}, a case which could arise if agricultural income from the crop under consideration accounts for a sizeable part of aggregate income.

negative correlation between P_{t-1} and A_{t-1} the estimates $\hat{b}_1$ and $\hat{b}_2$ are likely to err on the same side whereas the estimate $\hat{b}_3$ is likely to be unbiased. This would imply that any estimation error is compounded in the resulting elasticity estimate since b_1 and b_2 enter the numerator and the denominator in (5) with opposite signs.

While it is not possible to determine in general whether in the presence of such estimation errors the elasticity esimate is likely to err on the high or the low side, one may easily conceive of situations which are perhaps particularly typical of developing countries where the latter will occur. Suppose that a dominating random event like the weather affects the price prevailing at period $t-1$ and the planting decisions for period t in opposite directions. Such a situation may arise, e.g., if good weather at harvesting time is also conducive to planting the following crop or if the good harvest and the resulting poor market price induces farmers to retain a larger fraction of their output as seedstuff and thus to plant a larger area in the following season. If then the random term in the hidden demand function (6) tends to have the opposite sign of the disturbance v_t in (4) and if we maintain the assumption that w_{t-1} is independent of A_{t-1} and A_{t-2}, the estimates of b_1 and b_2 are likely to err on the low side, leading to an underestimate of the true supply elasticity. This explains perhaps in part the exceedingly low and sometimes even negative long-run supply elasticity estimates recorded for many developing countries in the compilations of Askari and Cummings.

Irrespective of whether one accepts the argument just presented or not, the fact remains that the presence of multicollinearity among explanatory variables leads to a loss of precision and is likely to result in a high degree of sensitivity of the estimated coefficients to changes in the observation period. As an empirical illustration for the latter which comes on top of the many indications contained in the compilations of Askari and Cummings consider the simplest extension of the basic Nerlove model consisting of the inclusion of a linear time trend in (4). Letting A_t represent the area under potatoes in Germany and P_t the producer price deflated by the price index for all field produce as published in the official statistics of the Bundesministerium fuer Landwirtschaft and estimating (4) using the Cochrane-Orcutt method to correct for (minor) serial correlation among the error terms produces long-run supply elasticities for the three 20-year periods ending 1975, 1976 and 1977 of .48, 1.18 and .23, respectively.[3] These dramatic shifts in the underlying parameter estimates in response to minor shifts of the observation period could, of course, reflect misspecification, but they may be due to the high degree of correlation between P_{t-1} and the remaining explanatory variables that was found in the data.[4]

[3] As to the question whether domestic demand was likely to have had an essential influence on domestic prices note that potatoes were not subject to price control during the observation period and that foreign trade played only a small rôle as domestic output covered invariably more than 90 per cent of domestic use.

[4] Running P_{t-1} against the remaining independent variables gave an R^2 ranging between .50 and .57 for the three periods mentioned. Incidentally, A_{t-2} contributed virtually nothing to explaining P_{t-1} which is consistent with the specification of the hidden demand function (6).

3. CONCLUSION

The reduced form of the Nerlove model is likely to be accompanied by a demand function type relationship between the explanatory variables P_{t-1} and A_{t-1}. As a result the reliability of the long-run supply elasticity estimate may seriously suffer, particularly if the conditions prevail under which estimation errors in the affected parameters would tend to compound each other. One special but perhaps not atypical possibility was briefly mentioned under which the supply elasticity estimate is likely to err on the low side. At any rate, the user of the Nerlove model is well advised to check for the alleged collinearity problem. Should it be present, there is, however, little he can do about it. Search for other relevant explanatory variables will not reduce the negative correlation between P_{t-1} and A_{t-1}. The other usual cure, namely dropping either of these variables, would alter the economic meaning of the underlying model. And finally, use of exogenous information on the demand relation (6) would not help either. While it is unclear where such independent information could come from, assume for the moment it were available. It is then easy to check along the lines of Johnston's example already quoted that the estimation of the reduced form (4) after substitution of the known relation (6) for P_{t-1} would neither change the likely bias, if any, nor the variances of the parameter estimates $\hat{b}_1$ through $\hat{b}_3$ which are needed in the calculation of the long-run supply elasticity.

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