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OUTPUT PRICE RESPONSE IN AGRICULTURE : AN EVALUATION

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Introduction

In the last decade, perhaps the most important influence on the study of agricultural supply response has been the seminal work of Marc Nerlove.[5]† His dynamic supply model, based on the concept of adaptive expectations, has been a central feature, though often with extensive modifications, in over a hundred studies.[1]

In this paper, it is not our intention to recapitulate their results, but rather to discuss some of the limitations of the Nerlovian model. We believe that this may be both helpful in evaluating the importance of this body of work and also in signalling some possible directions of future research.

The Nerlovian Model and Its Estimation

As has been indicated, the dynamic supply model has been stated in several versions by Nerlove and subsequent researchers. But the following three equations represent a frequently used form of the model :

$$(1) \quad A_t^D = \alpha_0 + \alpha_1 P_t^E + \alpha_3 Z_t + U_t$$

$$(2) \quad A_t - A_{t-1} = \gamma (A_t^D - A_{t-1})$$

$$(3) \quad P_t^E - P_{t-1}^E = \beta (P_{t-1} - P_{t-1}^E)$$

where : A_t and A_t^D are actual desired acreage planted in period t, P_t and P_t^E are actual and expected prices in period t, and Z_t represents other non-price factor(s) hypothesized as significantly affecting supply.

Desired output is thus expressed as a function of expected prices; though both are non-observable variables, equations (2) and (3) define each in terms of past observed values. Since inflexibilities may hinder the cultivator from making, in one period, exactly the acreage changes he may desire, the actual change, in any given period, is expressed as a portion of the desired change.

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We wish to thank the Journal referee for valuable comments but we remain responsible for any errors.

† Figure in parenthesis refers to the literature cited at the end of the paper.

1. For a detailed discussion of this, refer to our, Agricultural Supply Response : A Survey of the Econometric Evidence, sponsored for publication by the Center for International Studies, at M.I.T., 1974.

Price expectations are also framed in adaptive terms, with expectations shifting in each period by some fraction of the difference between the most recent actual and expected prices.

Nerlove originally expressed supply response in quantity rather than acreage terms, and some later writers have used this definition as well. However, as Nerlove himself pointed out, acreage would generally seem the more appropriate supply measure since the cultivator has a larger degree of control over area.[2] Output in tons is subject, for example, to vagaries in weather patterns which might severely distort any estimate of the farmer's response to price expectation. A number of non-price variables have been included in the basic supply equation, most commonly rainfall and crop yield indices, and simple trend variables intended to represent the effects of monotonic changes in both technology and/or in the supporting infra-structure.[3]

To estimate the Nerlovian model, [equations (1) through (3)] we can get a reduced form of the three equations. However, ordinary least squares cannot be employed in estimating this reduced form equation; if it is, certain difficulties will be encountered :

1. the estimation will be inefficient as the disturbance terms in the reduced form will probably be serially correlated, irrespective of the correlation of the original disturbance terms;

2. the simple least squares estimates will likely be inconsistent inasmuch as the equation contains lagged value of the dependent variable; and

3. the equation is over-identified, as the structural parameters cannot be uniquely recovered from the estimated parameters of the reduced form.

One way to approach this problem of efficiency and consistency is to maximize the likelihood function of the observation with respect to the b's. Under the assumption that the disturbance terms are distributed $N(0, \sigma^2 I)$, the following can be written as the log of the likelihood function :

$$(5) \quad L(\underline{A}\,\underline{X}, b, \sigma^2) + \frac{I}{2}\log(2\pi) - \frac{I}{2}\log\sigma^2 - 1/2\sigma^2(\underline{A}-\underline{XB})'(\underline{A}-\underline{XB})$$

2. In addition, using acreage as the response variable is appropriate when acreage data are more reliable.

3. Several applications of this model have been made to the supply of perennial crops, such as cocoa and coffee. These crops need considerable modifications regarding the expression of price expectations and stock adjustment, as well as a recognition of long-term effects of irregular occurrences, such as severe droughts or highly destructive blights or storms, which might be of only minor concern in explaining output variation for annual crops. Furthermore, some modifications to the basic supply model have been in part undertaken to avoid estimating difficulties, such as parameter identification problems. See Askari and Cummings. [1]

The likelihood function is maximized when the sum of the squared residuals is minimized. And the estimation of the b's can be obtained by solving:

$$(6) \quad \partial W' W / \partial b_i = 0$$

These estimates are consistent, asymptotically unbiased, and efficient.

Limitations of the Model

In estimating supply responsiveness, economists have had to resolve a number of conceptual problems relating to four basic variables of the model —output, price, weather and yield.

While acreage statistics, as has been mentioned, have proven more acceptable than other measures of response, in the estimation one is still assuming that all land is of a uniform quality. In many areas where annual changes in acreage are small or where a small fraction of total cultivable land is under crop this assumption may be reasonable. When acreage is used as the dependent variable in equation (1), any resulting elasticity will be that of acreage, not total supply, with respect to price. But as a result of different land qualities, the relationship between the acreage and output elasticities will change, as rising prices first induce planting on the best land and then expansion on to less suitable land. In such a case, a constant output elasticity would actually require an increasing acreage elasticity.[4]

As has been indicated previously, when response is described in acreage terms, intended cultivator reactions to changes in price expectations can be isolated from other variations, caused by external factors like climatological disturbances which affect crop yield in some unanticipated fashion. However, consistent treatment of the concept of adaptive expectations requires the consideration of the role played in supply determination by *anticipated* shifts in yield. Yield expectations thus must be defined in some manner analogous[5] to those of price if expected yield, a non-observable variable, is to be included in the basic supply equation.[6]

Short-run variations in weather are the most obvious cause of unexpected shifts in yield, and in many studies, some measure of weather has been in-

4. This problem can be somewhat solved by adding expected yield (Y_t^*) in the first equation of the Nerlovian model and adding another equation to the model for expected yield:

$$Y_t^* = Y_{t-1} + \frac{\beta_0 A_t^*}{A_{t-1}} + \beta_1 (Y_{t-1}^* - Y_{t-1}).$$

Thus, we essentially allow for a consideration of differentials in land yields.

5. Two methods of doing this are illustrated by Jere Behrman [3], who adds a fourth equation to the basic model, and Vahid Nowshirvani [6], who postulated that changes in price expectations depend upon past differences in observed and expected values of both price and yield.

6. Some studies have simply used actual in place of expected yield. While expedient, such an approach cannot be defended on theoretic grounds.

corporated into the supply equation. Inherently, such a move involves a conceptual dilemma : *actual* weather (for example, rainfall during the growing season) can hardly be a determinant, *ex post* of the desired acreage planted by non-clairvoyant farmers; on the other hand, the inclusion of *expected* weather, while faithful to the rationale of an adaptive expectations model, would require a definitive formulation. Not surprisingly, no scientifically satisfactory way of expressing this concept has yet been devised, though the incorporation of past yield (in the guise of yield expectations) involves recognition of prior climatological experience—this is done in another form in footnote 4.

Since the prime interest of most supply researchers is the identification of cultivator response to market influences, a concise statement of the price variable has been a major concern. Economically rational farmers are assumed to be income maximizers, which ideally requires consideration of both costs and returns at the producer level. Individual studies have employed different methods to account for the weight farmers give to alternate uses of available inputs and/or the discounting they make for the effects of inflation. Largely due to considerable differences in the type and quality of data published for different countries and crops, no single pattern emerges as the most preferable way of including prices in the supply model.

But the question of what price variable to use in the model confronts all researchers. Nerlove's discussion of prices is phrased mostly in terms of current market realizations, with normal or expected prices defined in terms of past market prices. Not surprisingly, many researchers, beginning with Nerlove, have inserted more realistic price formulations into supply analyses extending over a time period of more than a few years. The price series most frequently cited in their studies include :

(*a*) the price of the crop received by farmers;

(*b*) the ratio of the price of the crop received by farmers to some consumer price index;

(*c*) the ratio of the price of the crop received by farmers to some index of the prices of the farmers' inputs;

(*d*) the ratio of the price of the crop received by farmers to some index of the prices of competitive crops (or the price of the most competitive crop).

To leave aside for the moment the problem of choosing a deflator,[7] let us first point out that, given reasonable assumptions, it is quite possible that

7. Which is frequently determined by data availability.

none of these four price formulations may be the proper one to use in equation (3). To make this point, we ask : why would a farmer produce more of a particular crop? Several possible answers suggest themselves :

(1) He might produce more to increase his own consumption of the crop.

(2) He might produce more to keep his own consumption of this crop the same, in the face of rising input costs.

(3) He might produce more if he wishes to buy more of other goods.

(4) He might produce more in order to keep his consumption of other goods the same (if the relative price of such goods is going up).

If output is changing because of the second reason, then we could use as our price variable the ratio of the price of the crop to an index of input prices; alternatively the difference between crop and input prices, a profitability measure, could be employed. If producers are motivated by either the third or fourth reasons, on the other hand, then crop prices deflated by some index of consumer prices would be a reasonable measure of price, as would be crop price relative to that of alternative crop(s), an indication of income realized by the cultivators. But should they be motivated in large part by a desire to increase their own consumption, then no price variable seems very pertinent.

Therefore, in general we can see that it is not unlikely that the price formulation used in a supply model might have little or no relevance in cultivator decisions. It seems hardly necessary to point out that in most developing nations, farmers buy only a very select basket of goods (or none at all) and as a result, deflating by some consumer price index may be of dubious value. Using the relative price of two competitive crops (in production) also encounters difficulty. For instance, if the relative price of rice to wheat goes up a great deal in a period when other prices are constant, we might get a large increase in rice production; however, if most other prices had also changed, we might get a very different response.

Clearly, if we wish to justify inclusion of any specific price variable, we must know *why* the farmer wants to alter his production.

Thus even if one knew the correct price to use at any time, one would need a much more complicated price expectation equation because of possible changes over time. As a result, the use of an inappropriate price series casts some doubt on the empirical results and may also account for some of the response differences observed in various studies.

However, one general point regarding an inherent limitation of time-series analysis must be made. No matter how prices are measured, in any society when rapid economic changes occur (certainly the situation in many areas moving from traditional to market forms of production and consumption), it should be acknowledged that the proper price formulation itself is likely to change over time. Consumer price indices, for example, become more relevant as agriculture moves further from the subsistence levels; technological changes may radically alter the range of alternative crops the cultivator may consider. The longer the time period considered or the more relatively drastic the social changes concurrent with supply analysis, the more serious this price conceptualization problem will be.

Still another difficulty implicit in using the Nerlovian model is the assumption that acreage elasticity is constant for all ranges of possible price changes. But if we think of risk varying in proportion to how many eggs are being put in one basket, we can see no reason for proceeding, for example, from the knowledge that a 5 per cent increase in price leads to an equal increase in acreage to the assumption that doubling of price will result in a two-fold acreage jump. This objection might be less important in a situation where ample uncultivated land is available and one crop can be rapidly expanded without any others being cut back. But the effect cannot be ignored in any quasi-Malthusian case.[8]

Still another problem arises in the situation where output has been growing steadily, and then, in one particular year, the increment in output is much larger than had been normal, leading to an actual price decline. As a result, the farmer's price expectations for the period may have been quite far off. It only seems reasonable that the farmers would take this fact into account in calculating their expected price for the next period. In other words, the farmers' price adjustment process (here simply represented by the coefficient β) actually may depend upon a number of factors, such as changes in output and any exogenous occurrences which might influence prices. To partially remedy this situation, we might replace equation (3) by

$$(4)\ P^e_t - P^e_{t-1} = \beta(P_{t-1} - P^e_{t-1}) + \delta\,(Q^e_t - Q_{t-1})$$

where : Q^e_t is expected output, and

Q_t is actual output

thus allowing for variations in output, in the formation of price expectations.

8. Under these circumstances, uncovering the role of price inducements for more intensive cultivation is the more relevant direction for investigation—yield, rather than acreage, response to price.

Factors Affecting Price Response

Even if one assumes that *all* the problems outlined in the preceding section can be solved, and certainly several of the more extensive studies employing the Nerlovian model have made significant attempts to anticipate and answer some of these objections, the model can at best give an accurate estimate of the magnitude of the supply elasticity. While this knowledge is of undeniable importance to agricultural policy-makers, there remains unanswered the question as to what may be done to change the elasticity. Specifically, knowing the elasticity, gives the policy-maker only one policy tool, namely, a change in price to increase output. But the resulting change in relative prices could also lead to distortions in the economy. Supply analysis can reveal differences, for example, in the responsiveness of the cultivators of a single crop from one region to another, or in the same region for different crops; but it offers few clues as to *why* such differences exist.[9]

To enlarge the scope of what the model can offer the policy-maker, we can postulate that the degree of farmer responsiveness is governed by a number of market and non-market factors. We have elsewhere set forth (and empirically tested) such a hypothesis[10] which can be summarised as follows. Market responsiveness (in terms of supply elasticity) can be expressed as a function of:[11]

(*a*) soil fertility—all other things equal, the cultivators with more fecund holdings should be more responsive to market influences;

(*b*) average size of holding—isolated from the influence of relative fertility, a similar positive relationship should hold between this factor and responsiveness;

(*c*) cultivator's income—richer farmers would be expected to be more market-oriented than their more marginal compatriots;

(*d*) land ownership patterns— if "being one's own boss" makes a cultivator more responsive to the market, a positive link should be indicated between a measure of owner-cultivated acreage and elasticity;

(*e*) literacy—a proxy for the openness of farmers to available modern techniques, with another positive relationship expected;

9. Computed elasticities, based on time-series analysis, are *averages* over the period considered, and might be considerably different from the actual values at the end of the period, particularly, for example, in a rapidly developing society.

10. Askari and Cummings [1], Chapter nine. Other factors affecting cultivator responsiveness were considered and discussed, but only those that proved possible to include in the statistical testing of the hypothesis, are mentioned in this paper.

11. The larger the number of explanatory variables that are used, the lower will be the degrees of freedom. And thus given the limited availability of time-series data, one is restricted to the more important variables.

(*f*) the extent of irrigation facilities—since such projects increase the yield and the flexibility of land use, responsiveness should be positively influenced by increasing land under irrigation;

(*g*) the availability of unused cultivable land—to the extent this would enhance the range of options open to the cultivators, another positive relationship would be anticipated;

(*h*) risk—here the indicated sign of the parameter estimate would signal important information to the policy-makers. For risk associated with prices, a positive parameter would be consistent with a basically entrepreneurial outlook and favour policies utilizing market forces to regulate crops output. Negative estimates would indicate risk aversion and the likely success of price stabilization measures. Risk defined in terms of weather would be expected to be negatively linked to responsiveness (though the magnitude of the coefficient might vary widely, depending upon the hardiness of the crop); and

(*i*) the relative importance of the crop in question—here again the sign of the estimate would supply some necessary information for policy formulation. The question to be answered is whether farmers are more responsive for more important crops, with which they are presumably more familiar or for relatively minor crops for which it can be argued the possibilities for expansion are greater—since land suitable for such a crop is less likely to already be devoted to its production.

The results of such a test of the factors affecting responsiveness gives the policy-maker a whole new range of additional tools without resorting to changes in relative price; and an easy way of determining elasticity of response may be also available from such estimates—as it can be estimated from a simple equation where the independent variables are the above.

Since the required statistical information is regionally compiled, the testing of such a responsiveness hypothesis is cross-sectional by nature and aggregative by necessity. However, a fundamental objection can be raised to this essentially macro-economic approach. Aggregate data of course represents average measures which can easily mask large differences within the group or region which, if known, could significantly affect the results. For example, we might postulate that higher farm income, *ceteris paribus*, calls forth greater responsiveness from the cultivators. However, one can question the wisdom of testing such a hypothesis using income data which might in one district be relatively high, as an average of a tiny feudal land-owning class and a barely surviving mass of quasi-serfs (neither of which groups might be much influenced by modern market forces) and in another region be somewhat lower but represent the earnings of cultivators based on a fairly equitable distribution of acreage.

On the other hand, micro-economically-oriented studies[12] of the farmer's responsiveness allow the researcher the opportunity to obtain in-depth knowledge of the sample being considered, often as the result of personal observation. If sufficient data were available from such studies to allow testing of hypothesis expressing responsiveness in terms of various market and non-market factors, the analysis could take account of peculiarities noted about the samples and make use of data gathered by, and according to the specifications of the researcher.

Conclusion

The value of the Nerlovian model as an analytical tool must certainly be recognized; the scores of studies published in recent years have greatly expanded the body of accurate information available to the formulators of agricultural policies. Recognition, however, must also be made of the limitations on what can be gained from this kind of supply analysis. Most of the Nerlovian-based studies have been undertaken in the spirit inspired by W. Arthur Lewis' monumental work [4]—as a result of the new-awakening, in the late 1950's, to the importance of agriculture in the process of economic development, of the realization that the success of any industrialization programme would depend upon mobilizing the surplus of a healthy agricultural sector.

However, the lack of information as to how to influence the magnitude of cultivator responsiveness can no longer be compensated for, as perhaps it could in the part, by a trial-and-error policy procedure. In the coming years of chronic shortages, mistaken or ineffective policies will not merely lead to a slowing of the rate of growth in the "modern" sectors but could lead to a lengthy hiatus or even reversal in the movement away from bare subsistence living standards. In fact, the spectre of massive famine in areas like India or sub-Saharan Africa can no longer be dismissed as mere wolf-crying —the "right" combination of ill-conceived policies and bad luck in weather patterns could spark a nightmare of catastrophic proportions, with little advance notice and even less prospect of significantly easing the disaster from the now nearly bare cupboards of the traditional food-stockpiling nations.

If econometric analysis is to provide any guidance along the narrow path policy-makers must tread in the future, a new generation of evidence must be uncovered and evaluated. We believe our study of factors affecting responsiveness [1] is a first step in adding a range of macro-economic tools to the decision process. However, the essential complementary of a micro-economic approach has yet to begin, on the scale necessary to provide reliable answers and to equip policy-makers with further policy tools to increase agricultural output.

12. For example, those of K. L. Sharma and M. P. Gupta [8], Kalpana Bardhan [2], and David Pfanner [7]; the essential complementarity of the two approaches is emphasized by the comment of the eminent Indian social anthropologist, M. N. Srinivas : "Micro-studies provide insights while macro-studies yield perspectives, and movement from one to the other is essential."

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