Agricultural Supply Response and Industry Structure

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The effects of price changes on the supply of agricultural products have been examined in literally hundreds of studies (Shumway, Askari and Cummings). These studies assume that factors other than price also affect supply, but the role that industry structure plays in supply response is not explicitly considered. Other studies, those intended to examine effects of farm size restrictions, have occasionally addressed the relationship between aggregate output and structure. For example, several studies were concerned with the 160-acre limit of the Reclamation Act of 1902 (Martin; Hall and Leveen; and Moore). In another context, Berck and Levy show a relationship between output and land distribution on Israeli moshavim.

In this paper, a theoretical basis for examining both the supply and structural effects of agricultural price changes is proposed. It is argued that prices play a role in determining industry structure, and that this structural effect must be considered in the analysis of aggregate supply response. We argue that, unless it is assumed that all farms are identical, changes in the composition of farms classified according to key characteristics will affect aggregate agricultural supply. We focus on farm size (as measured in land acreage) as the key source of heterogeneity among farms.

Conceptual Framework

The theoretical discussion presented here will assume a fixed number of tillable acres. Farmers may freely shift from one crop to another, but if no crop is to be planted, the land must be left idle.

The decision on whether to idle land is dependent on a composite price of all crops. There are many farms, each of which is either "small" or "large", and the large farms are assumed to have both lower per-unit production costs[1] and higher yields[2] than do the small farms.

Aggregate production is described as:

$$Q = Y_1 L_1 + Y_2 L_2 \tag{1}$$

where Q is aggregate production, Y_1 and Y_2 are average yields per acre for small and large farms, respectively, and L_1 and L_2 are the number of total acres in small and large farms, respectively.

Since land is of fixed supply, we also have

$$\bar{L} = L_1 + L_2 \tag{2}$$

where $\bar{L}$ is the fixed amount of land available.[3] We can therefore rewrite (1) as the following:

$$Q = Y_1 L_1 + Y_2(\bar{L} - L_1). \tag{3}$$

Differentiating with respect to price, aggregate supply response is:

$$\frac{dQ}{dp} = \frac{dY_1}{dp} L_1 + (\bar{L} - L_1) \frac{dY_2}{dp} + (Y_1 - Y_2) \frac{dL_1}{dp}. \tag{4}$$

Theory suggests that both small and large farms will adjust production with respect to price changes so that

$$\frac{\partial Y_1}{\partial p} > 0, \frac{\partial Y_2}{\partial p} > 0. \tag{5}$$

L_1 and $(\bar{L} - L_1)$ are also assumed positive, so if we ignore the rightmost term in (4), aggregate supply response is clearly positive with respect to price.

The rightmost term of (4) is routinely ignored in supply response estimation. To ignore the term, at least one of the following two conditions must hold:

$$Y_1 - Y_2 = 0, \text{ or} \tag{6}$$

$$\frac{\partial L_1}{\partial p} = 0. \tag{7}$$

For the first of these two conditions to hold, yields must be the same for small and large farms. But yields are higher for large farms by assumption, so we have

$$Y_1 - Y_2 < 0. \tag{8}$$

For condition (7) to hold, the numbers of small and large farms must be independent of product prices. We will now turn our attention to the reasonableness of making such an assumption.

Price and Farm Structure

We have assumed both small and large farms, with the small farms having higher unit production costs than the large farms. Price is presumably above the cost of production for both farm types since farms of both types are able to operate. Now suppose that price falls into the range which is above the production costs for the large farms but below those for the small farms. It is generally assumed that the small farms will leave the industry.

What is meant by the term "farm"? In most industries, the firm and the assets of that firm are one and the same. If the firm leaves the industry, its assets are removed from production. The principal asset of grain farmers is land, however, and if a farmer leaves the industry the land does not necessarily follow. In fact, quite the opposite is observed. For example, USDA reported that "the 387 million acres of cropland used for crops in 1982 equalled the 1949 level" (p. 6). During that same time period, the number of U.S. farms fell by more than half from 5.4 million to 2.2 million (U.S. Bureau of the Census). We must therefore be careful to define a "farm" not as a farmer but as a particular tract of land being farmed.

A price change which forces a farmer out of business may not force the land out of production. In the case now being considered, production costs of large farms are such that profitable production is still possible. It is therefore likely that a neighboring farmer or another agent will combine the land of the small farm into a large operation in order to take advantage of lower production costs. This is a crucial difference between grain farms and, say, manufacturing plants. It is relatively costless to combine small farms into larger ones; it is all but impossible to combine small manufacturing plants into larger ones. Thus small manufacturing plants can be forced out of production by the same forces (lower prices) that serve to make the grain industry more efficient.

Why do small farmers not leave voluntarily from the hypothetical economy during times of higher prices? Profit maximizing behavior would indicate that a move to combine these farmers' land to form larger, lower cost firms would be advantageous regardless of output price. And yet the small farmers leave only when forced out of the industry by prices which make survival impossible. These farmers are not pure profit maximizers, but ones who will make considerable sacrifices to stay in farming. In the appendix we formalize this argument showing that if farmers attribute a value to remaining in farming they will accept a lower income in farming. For each farmer there is a critical or maximum value that he or she is willing to forego in order to remain in farming. If that critical value is exceeded, then the farmer will exit. More importantly, it is also shown that under plausible conditions, the proportion of small farmers that exit will be inversely related to farm output prices. Since costs depend on farm size, agriculture operates at higher total costs than would be the case if all farms were combined into sizes that could fully take advantage of size-dependent cost savings.

Falling prices now have a new role to play. They may force farmers and their land out of production, but this is not what is usually observed. Most of the time, farmers leave but their land stays in production. What is happening in these cases is that falling prices are allowing the industry to lower its overall production costs by creating opportunities to combine small farms into larger ones. These adjustments do not occur voluntarily because smaller farmers do not want them to occur voluntarily. And as long as small farmers hold on to their land and the supply of land is fixed, there is no other way for the potential of size-dependent lower production costs to be realized.

In the view of this paper, then, falling prices may well force farmers out of the industry. But as these farmers leave, their land will be combined into more efficient units in which production at the lower prices is still profitable. We therefore assume that (7) does not hold. Instead, we argue that the following is the case in the hypothetical agricultural economy:

$$\frac{\partial L_1}{\partial p} > 0 \qquad (9)$$

Supply Response

We can now return to the task of analyzing supply response. In equation (4), supply response was shown to be the sum of three terms, the first two of which were positive. The third term, however, is the product of two terms of opposite signs if (8) and (9) hold and is therefore negative. The expected sign of the aggregate supply response is therefore indeterminate. This conclusion in no way implies that individual farmers will not react to price changes in the usual way. While a few studies such as the one by Just and Zilberman suggest that individual farmers may not show a positive correlation between price and output, most studies assume this positive relationship. And, too, does the discussion here.

Where this study departs from many others is that it does not reason directly from the behavior of individual farmers to the behavior of the farm economy. To do so within the framework presented in this paper would be a clear example of the familiar "fallacy of composition." (Copi, pp 79-80). That is, aggregate supply response cannot be determined as the simple sum of the actions of individual agents. The right-most term in equation (4) makes the whole different than the sum of the parts. Price-induced structural effects dampen the positive reaction to price changes by individual farmers.

The supply response effects presented here can be shown graphically. In Figure 1, two profit-maximizing firms are shown in a way suggested by Henderson and Quandt (p. 149-152). Firm A has lower production costs per unit than does Firm B. At price P_1, both firms produce. When price falls to P_2, Firm B leaves the industry but Firm A continues to produce. At price P_3, both firms leave the industry and the total amount supplied by the two firms is zero. This argument is one way to explain the existence of firms of different efficiencies in the same economy while preserving the expectation of a positive relationship between supply and price.

The familiar argument presented in Figure 1 makes the critical assumption that both Firm A and Firm B are being operated at their maximum efficiency, even though costs differ between the firms. If the operator of B leaves the industry, there is no incentive for the operator of A to make use of B's productive assets. To see why this need not be the case in agriculture, consider a particular tract of land of a size equal to one small farm. Firm A is that land farmed as part of a large farm; Firm B is the same land farmed as a small farm. We now interpret Figure 1 as follows: Firm A shows the costs faced by large farmers for production on a certain tract of land; Firm B shows the (higher) costs faced by small farmers.

In Figure 2, both sets of cost curves are superimposed on the same graph. We assume that initially price is P_1 and the land is operated as a small farm. Production is therefore at level Q_s. If price falls to P_2, the small farmer leaves the industry, but the large farmer can still make profitable use of the land. Therefore, production now occurs in such a way that quantity supplied is Q_L. When price falls to P_3, the land is left idle and production falls to zero.

When price falls below the point the small farmer can continue to operate, a structural change occurs. This structural change leads to some unusual supply response expectations. For prices above P_1 and below P_3, we have the usual result that price and quantity are related in a positive way. But there is a discontinuity at the point of the structural change. At this point, there may be an increase in supply resulting from a decrease in price. There may also be a range of prices below P_2 in which output is higher than at some prices above P_2 because the large farmer is assumed more productive.

Apart from problems with expected signs, there is a second difficulty for supply response estimation inherent in Figure 2. The discontinuity results only for price declines. Falling prices force a structural change, but there is little incentive for rising prices to bring the small farmer back. At any price level, it will be easier for large, efficient farms to remain in business than for new small farmers to enter. Once small farmers leave, rising prices have the usual effect of causing the large farm operator to try to increase supply for the tract of land. This will also be the behavior for the small farmer when faced with price increases. Because of these factors, it is possible for a price movement from P_1 to P_2 to P_1 to show one production level for the first occurence of P_1 and another for the second occurence. This is illustrated in Figure 2 by points S, L, and M.

Conclusion

Edwards argues that the productivity of the farm sector is partly a function of structure. This paper extends his argument to include price effects on structure. In summary, the argument here is that price changes have two opposing effects on aggregate supply. One is a positive relationship between price and amount supplied by individual producers. The second is a negative relationship between aggregate supply and price resulting from structural shifts to farms of higher productivity.

The extent to which supply response results derived here can be extended to the real world remains an empirical question. No attempt was made to estimate an equation similar to (4); the data and specification requirements are obviously substantial. The analysis presented here does, however, give reason to doubt the aggregate supply response has an "expected" sign which can be determined *a priori* from theory. This result follows not from the price response behavior of individual producers, but from the structural effects of price changes.

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Table 1. Major uses of cropland, United States, 1949-1982

Cropland	1949	1959	1969	1978	1982
	million acres				
Cropland used for crops	387	359	333	369	387
Cropland harvested	352	317	286	330	350
Crop failure	9	11	6	7	7
Cultivated summer fallow	26	31	41	32	30
Idle cropland	22	33	51	26	20
Cropland pasture	69	66	88	76	67
Total cropland[1]	478	458	472	471	474

[1]includes the 48 conterminous States.

Source: USDA.

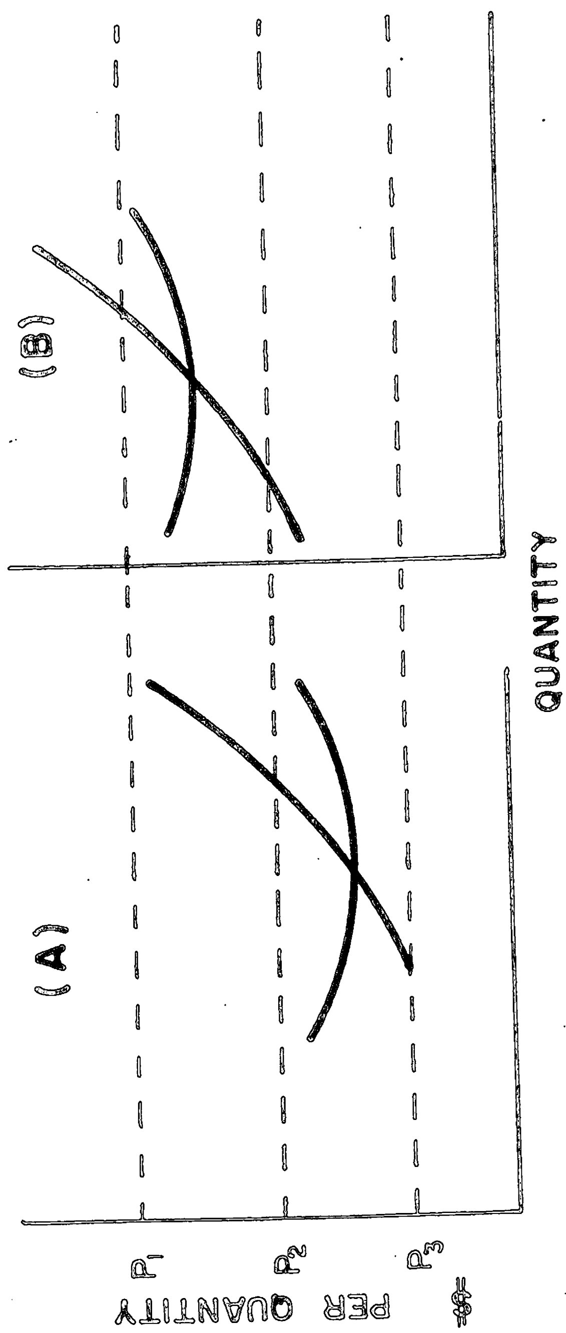

Fig 1

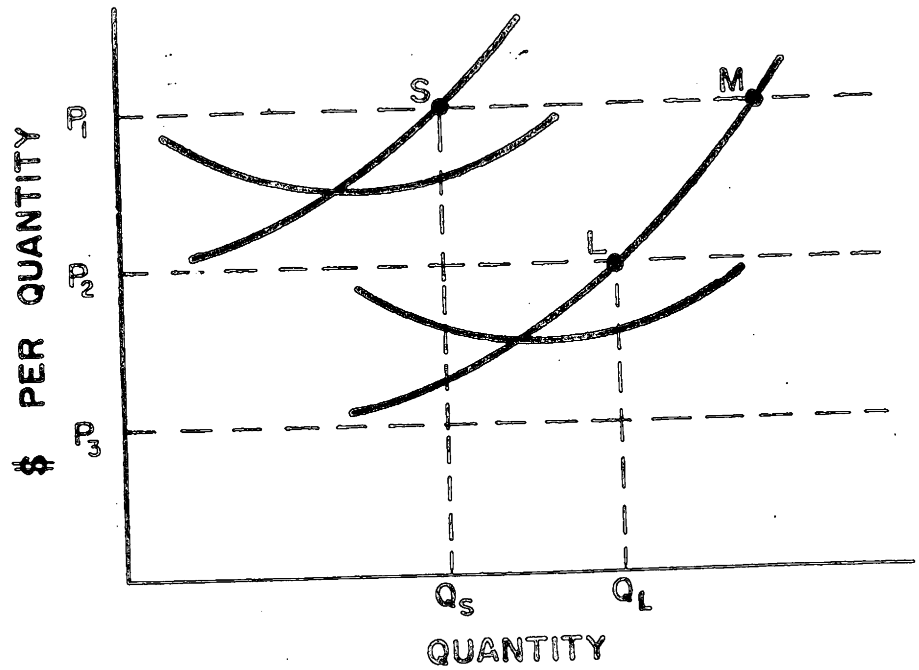

 Fig 2

Appendix

In this Appendix, we formalize the discussion of behavioral differences between small and large farm operators. The maximum profit of a large farm is

$$\pi_2 = S_2 \, h(p)$$

where π_2 is the revenue of large farmers, S_2 is the number of acres in a "large" farm, and h(p) is the profit per acre. Profit is a function of output prices, p, where $h'(p) > 0$. (For simplicity of notation, we ignore input prices).

Similarly, the maximum profit of the "small" farms is

$$\pi_1 = S_1 \, g(p)$$

where g(p) is the profit per acre, also an increasing function of output prices, and S_1 is the number of acres in a "small" farm. We assume that $S_2 > S_1$ and, consistent with the hypothesis that large farmers are more efficient than small farmers, $g(p) < h(p)$.

Large farmers will be willing to pay up to h(p) per acre for (renting) the land of small farmers. Hence a small farmer will exit if

$$S_1 \, g(p) + \lambda_i - S_1 \, h(p) < 0$$

where λ_i is the utility value attributed by the small farmer to remain in farming in dollar terms. The parameter λ_i is specific to farmer i since it depends on the structure of preference or utility of each farmer. Moreover, λ_i is not likely to be constant, and it can be defined by considering farmer i's utility maximizing decisions:

$$\max_{x} \mu^i(x^i, F)$$

$$\text{s.t. } qx^i = S_i\, g(p) + z^i \equiv Z^i$$

where μ^i is farmer i's utility function, x^i is a vector of consumption goods of farmer i, F is a binary parameter equal to 1 if farmer i remains as a farmer and 0 otherwise, q is a vector of consumption good prices and z^i is non-farm income. (Z^i is explicitly defined as the total value of consumption of farmer i.)

The maximum utility or indirect utility function associated with farming is obtained from the above problem as:

$$v_F^i = v_F^i(q,\ Z^i;\ 1)$$

Define now an indirect utility associated with non-farming, compensating for any income differential:

$$v_N^i = v_N^i\ (q,\ Z^i;\ 0)$$

where we are evaluating the maximum utility of non-farming at the same income level as farming (Z^i). Hence, λ_i is now defined:

$$\lambda_i = v_F^i(q, Z^i; 1) - v_N^i(q, Z^i;\ 0) > 0$$

that is, λ_i is the utility differential between farming and non-farming, evaluated at identical income or expenditure Z^i. Then

$$\frac{\partial\lambda_i}{\partial p} = \frac{\partial v_F^i}{\partial Z_i} S_1 \; g' - \frac{\partial v_N^i}{\partial Z_i}\frac{\partial Z_i}{\partial p}$$

and, since $\frac{\partial Z_i}{\partial p} = 0$ for non-farmers,

$$\frac{\partial\lambda_i}{\partial p} = \frac{\partial v_F^i}{\partial Z_i} S_1 \; g'$$

which is positive under the assumption that the marginal utility of income is greater under farming than when the individual i becomes a non-farmer. That is, under this assumption,

$$\frac{\partial\lambda_i}{\partial p} > 0.$$

Define now the critical value of λ that will make a small farmer to be on the margin of exiting, λ_c,

$$\lambda_c \equiv S_1[h(p) - g(p)] > 0.$$

Hence, farmer i will exit if

$$\lambda_i(p) < \lambda_c(p).$$

The proportion of farmers exiting at a given price p will depend on the value of $\lambda_c(p)$ and the distribution of the $\lambda_i(p)$. In general we know that

$$\frac{\partial\lambda_c(p)}{\partial p} = S_1 \left[h' - g'\right] > 0.$$

That is, the critical value decreases as output prices fall. Similarily, since $\frac{\partial \lambda_i(p)}{\partial p} > 0$ we have that $\lambda_i(p)$ for any farmer falls as output prices decrease, that is, the density function of the λ_i value moves to the left as p falls. A higher proportion of small farmers is therefore likely to exit when prices fall.

Footnotes

1) Hall and LeVeen found that total production cost per dollar of sales for cash grain farms in the largest size group was approximately half of that of the smallest size group. Furthermore, Aly et al. conclude that, for Illinois grain farms, "larger farms are indeed more efficient than small farms" (p.76).

2) Edwards has conducted an extensive review of census data to determine yields by farm size for several agronomic crops. It was his conclusion that "larger farms consistently tend to have higher yields" (p. 10).

3) The assumption of a fixed supply of land is critical. Without the assumption, equation (4) becomes simply

$$Q = Y_1 L_1 + Y_2 L_2$$

where L_2 is the amount of land in large farms. Equation (5) is replaced by

$$\frac{dQ}{dp} = Y_1 \frac{\partial L_1}{\partial p} + L_1 \frac{\partial Y_1}{\partial p} + Y_2 \frac{\partial h}{\partial p} + L_2 \frac{\partial \gamma_2}{\partial p}$$

in which all terms are positive. There is no room for a structural effect or the dampening effect on aggregate supply due to structural changes.

In his very definition of "land", Marshall included it among those things that "are given as a fixed quantity by nature and have therefore no supply price" (p. 120). More recently, Burt has argued that "quantity [of land] supplied is fixed in a given year" and that "the amount of farmland available may change gradually over time, but these changes are relatively insensitive to farm prices" (p. 11). Some empirical evidence concerning U.S. cropland is given in Table 1. It seems reasonable to conclude that farmland is not completely fixed in supply, but neither is it infinitely flexible in supply as is assumed in (10). If we must choose between the "simplifying assumptions" concerning land supply inherent in (3) or (10), we see no real problem in choosing those underlying (3).

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