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The aggregate supply functions of US agriculture, 1910-1965

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Summary

Knowledge of the supply-function of agriculture is important. There still are some problems in this field, which can be solved by applying concepts as net product, net price and net productivity and a new interpretation of the 'normal price' concept for dynamic conditions. This enables us to estimate the short run and long run supply elasticities for U.S. agriculture for various periods, which in their turn have been used to test some hypotheses on supply-behaviour of U.S. farmers.

Introduction

Knowledge of the aggregate supply function of US agriculture is important as well from an analytical point of view as from the standpoint of planning of price and income policy measures. The nature of this supply function has been a debated subject and there still are emperical and theoretical problems in this field (Hillman, 1967). It seems to me that by applying some new concepts and formulations some of these problems can be solved.

Agricultural output, production and supply

Farming or agriculture (in the conventional sense of the word) is a part of agribusiness, that is the productioncolumn for food and fiber. There are several stages in the production of food and fiber; in each stage of production the 'amount of utility' in a product is increased. The products leaving agriculture have more utility than the products entering agriculture. The amount of utility leaving agriculture is here called *output* of agriculture. The amount of utility leaving agriculture, however, is not the amount that is produced in or by agriculture. The amount agriculture itself has produced is the difference between the utility leaving agriculture and the amount that entered agriculture. This contribution agriculture has in the production of food and fiber is here called *production* of agriculture. The money value of this production is the net value added by agriculture. We can, therefore, also say production is the quantity component of net value added. Besides a quantity component there is also a price component here called *net price*. It is essentially the margin between the price level of the supplied means of production to agriculture (or intermediate products) and the price level of total output of agriculture.

Agriculture can only 'supply' what it produces. We may expect that the amount it will supply depends on the-state-of-the-arts in agriculture and the net price level. So we arrive at the following concept for the 'supply function' of agriculture:

$$N = f_1(A,P) \tag{1}$$

in which N = (net) product, A = state-of-the-arts in agriculture or level of agricultural productivity and P = price level of net product.
Agricultural productivity changes over time as a consequence of technical progress, causing shifts of the supply function. We assume that:

$$N = A(t) \,.\, f_2(P) \tag{2}$$

in which A(t) is the index of technical progress in agriculture, defined as the index of net product per unit of factor input. This index of US agriculture has been estimated by Van den Noort (1968).
If we call $N/A(t) = n$, we get the following expression for the basic supply function:

$$n = f_2(P) \tag{3}$$

The function for various years can be arrived at by multiplying this expression by the 'shiftfactor' A(t).
Price, productivity and product as defined here have never been used in supply analysis, the difference with the more conventional formulations (Cochrane, 1955; Nerlove, 1958; Griliches, 1960) is, therefore, obvious.

Price expectations

It is well-known that the agricultural product supplied at moment *t* cannot have been determined by the prices of that moment, for these prices were fully unknown at the start of the production. Probably there are some time lags or better still there may be multiperiod determination. It is a useful theory to expect that farmers have an idea of 'normal prices' as defined by Nerlove (1958). In this theory use has been made of the concept of price expectation. The expectations are a link between the present and the future, and they are one of the keys to study processes by which decisions are made. The planned production for period t ($= N_t = n_t \; A_t$) is dependent of the expected price ($= P_t^*$).
Let us assume that the relative change in production ($\triangle n/n$) is a linear function or proportional to the relative change in expected normal price ($\triangle P^*/P^*$) so that the planning function is:

$$\log n_t = \log a_o + a_1 \log P_{t-1}^* \tag{4}$$

in which P_t^* is called expected normal price and a_1 the long run supply elasticity.
We assume also that the price expectation function is:

$$\log P_t^* / P_{t-1}^* = b \log P_{t-1} / P_{t-1}^* \tag{5}$$

in which *b* is called elasticity of price expectation. This results in the following supply relationship:

$$\log n_t = b \log a_o + a_1 \, b \log P_{t-1} + (1-b) \log n_{t-1} \tag{6}$$

In the real world not only P changes over time but all prices do more or less. This has as a consequence that farmers will not react to changes in the *nominal* value of P (called P_n), but only to *real* value of P. What is the real value of P in this connection? We could for example deflate the index of P_n by the index of the general price level, or by the index of the cost of living of farmers. It seems to me that there is also another possibility. We can deflate the index of P_n by the price index of the factors of production (P_f). If farmers try the maximize their profits or minimize their losses we may expect that farmers will expand their production if the price of their product increases more than the price of the factors of production (and reversed). From this standpoint it is the best solution to read for the index of P in the above formula the price ratio of P_n and P_f (or index P_n/index P_f) [1].
In this theory two important coefficients play a role: a_1 and b. We may not expect that these coefficients are constants. The coefficient a_1 depends on the technical possibilities and the psychological willingness to react. So we may expect that if technology changes and if generations of farmers with a different attitude and cultural pattern appear the coefficients may be changed. The same holds probably for b because these coefficient is dependent on the amount and quality of information, the character of the farmers (optimistic, pessimistic; riskfearing or not etc.) and the experience farmers had with price changes. So if communication improves and a new generation of farmers comes into business it is not so strange to say that the elasticity of expectation can change; it is also possible that a dramatic experience with price changes (as a depression) can change the whole 'expectation function', just as the establishing of price support programs can do. Because of these possible changes in the expectation model, we may not expect that the supply-relation of agriculture can be described with one formula for the whole period 1910–65. It is reasonable therefore to divide this period in overlapping parts (of the length of one generation for example) and to try to find a regression formula for each of these periods.

Statistical estimates and some conclusions

We tried to estimate the supply function as formulated in formula (6). The results of the regression analysis are summarized in Table 1 and 2. The 'length of a generation' is chosen to be 20 years (see Table 1).
In agricultural economics literature there has been an extensive discussion about the backward-sloping supply curve, that is a curve with a negative elasticity. From my estimates it follows that the short run or long run supply elasticity has not been negative; so in the aggregate it is probably not a persistent behaviour to increase production if farm prices go down.
Most economists agree that the short-run supply relation for the national farm is highly inelastic, they may skirmish, however, among themselves with respect to just how inelastic this relation is. Some are of the opinion that the short run supply curve is completely inelastic (Cochrane, 1958), whereas others deny this (Griliches,

[1] Note: Index $P_n = (\Sigma W_p M_t - \Sigma W_s S_t) / (\Sigma W_p M_o - \Sigma W_s M_o)$ and Index $P_f = (\Sigma W_f F_t) / (\Sigma W_f F_o)$ in which W = weight coefficient (p indicates output, s supplied means of production and f factors of production), t = time, M = price index of agricultural output, S = price index of the supplied means of production, and F = price index of factors of production. These index numbers and weights are estimated by Van den Noort (1968).

Table 1 Regression coefficients for supply relation defined in formula (6) for the various periods of 20 years on basis of data published by Van den Noort (1968)

Mid of Period	*Regression coefficient of*		*Regression coefficient of*		R^2
	log n	*standard error*	*log* P	*standard error*	
1921	0.860	0.272	0.002	0.038	0.373
1922	0.793	0.220	0.007	0.035	0.485
1923	0.771	0.218	0.015	0.031	0.497
1924	0.742	0.277	0.033	0.040	0.328
1925	0.720	0.233	0.032	0.036	0.382
1926	0.744	0.239	0.030	0.037	0.398
1927	0.628	0.246	0.027	0.039	0.307
1928	0.586	0.250	0.019	0.042	0.280
1929	0.616	0.246	0.031	0.046	0.292
1930	0.581	0.238	0.012	0.048	0.314
1931	0.732	0.251	0.041	0.051	0.379
1932	0.710	0.260	0.041	0.050	0.358
1933	0.657	0.249	0.027	0.045	0.336
1934	0.642	0.241	0.022	0.037	0.330
1935	0.580	0.250	0.006	0.037	0.296
1936	0.621	0.258	0.001	0.039	0.333
1937	0.727	0.261	—0.001	0.040	0.422
1938	0.791	0.241	0.003	0.040	0.518
1939	0.810	0.228	0.002	0.040	0.573
1940	0.899	0.216	0.011	0.040	0.623
1941	0.802	0.167	0.010	0.034	0.666
1942	0.826	0.165	0.016	0.035	0.647
1943	0.868	0.152	0.030	0.042	0.664
1944	1.015	0.121	—0.001	0.038	0.807
1945	1.028	0.106	0.005	0.037	0.852
1946	1.054	0.100	0.011	0.036	0.883
1947	1.053	0.070	0.015	0.026	0.948
1948	1.072	0.066	0.009	0.025	0.960
1949	0.977	0.075	0.025	0.030	0.960
1950	0.897	0.094	0.066	0.036	0.960
1951	0.809	0.118	0.094	0.045	0.970
1952	0.698	0.092	0.123	0.034	0.984
1953	0.647	0.086	0.133	0.031	0.986
1954	0.610	0.073	0.138	0.026	0.990
1955	0.582	0.088	0.150	0.030	0.990

The regression coefficient of log n_{t-1} is $(1-b)$ in which b is the elasticity of price expectation. The regression coefficient of log P_{t-1} is the short run price elasticity of supply ($a_1 b$). The long run supply elasticity is a_1.

1960). It seems to me that both can be right, it depends on the period in question. It appears from Table 1 and 2 that the short-run supply elasticity in the pre-war period (1910–41) did not differ significantly from zero, but after 1941 this changed: the short-run elasticity increased and the average elasticity in the period 1945–65 was about $+0.15$.

There has also been some discussion about the difference between the short and long run supply elasticity. In the period 1911–41 the long run supply elasticity did

not differ significantly from zero, but became more elastic, because for the period 1945–65 we found a reliable estimate of 0.358 (see Table 2). So we may conclude that the supply of agriculture on long-run is far more elastic than on short-run.
The coefficient b out of the expectation model changes over time. This is in accordance with our theory and explains the 'instability of the distributed lag model' described by Griliches (1960). These changes prevent the use of just one regression formula for the whole period, such a function is not always reliable. From formula (5) it follows that if b were equal to zero the actual prices would have no effect whatsoever on expected normal prices. On the other hand, if b were equal to one expected normal price would be equal to last year's actual price. Now b has increased, indicating that the expected normal prices are approaching last year's prices. I think this is the result of the price- and income policies, which give farmers a rather high degree of price stability. They do not expect that next year prices will be very different from this year's prices.
The supply behaviour of US agriculture in the period 1940–65 can almost completely be explained by the described model, because the coefficient of multiple determination (R^2) varies from 0.96 to 0.99. This, however, is not the case for the period 1910–1940. So farmers appeared not to be very price sensitive, in the period 1910–1940, because production did not change under changing price conditions. There are several possibilities to explain this. A very reasonable explanation seems to me the hypothesis of 'economic mobility' of agricultural factors of production. It has been argued that the price elasticity of supply of agricultural product depends on the supply elasticity of the factors of production in agriculture especially labor (D. G. Johnson, 1950; Van den Noort, 1966). This supply elasticity of labor depends on its economic mobility [2]. A high price elasticity of supply of factors results in a high price elasticity of supply product and reversed. In the pre-war period, when supply of labor was inelastic the supply elasticity of agriculture was very low or zero (because of widespread unemployment), in the period after 1941 the supply of labor became more elastic and we see that this coincides with a higher supply-elasticity of agriculture. Increasing economic mobility of factors will enable farmers to react more to changes in prices. Changes in prices are then more and more accompanied by changes in production, or in statistical terms the coefficient of multiple determination (R^2) will increase just as we see in Table 1.
The supply function defined and estimated in the preceding paragraphs gives only a description of the supply behaviour of US agriculture. It should be understood that this does not mean that we have 'explained' this behaviour. We have not explained technological progress, factor mobility, and the way farmers form their price expectations. It is obvious that an explanation of these factors is only partly an economic problem. In this analysis these factors are considered as *exogeneous* factors.

[2] An inelastic supply of a factor of production in agriculture is accompanied by a relative large divergence between its 'salvage value' (s) and 'acquisition cost' (a). Increase in supply elasticity goes hand in hand with a decrease of the difference between a and s and reversed. So there is a close link between this theory and Johnson–Hathaway's theory of 'fixed assets in agriculture'. Thus with the classical concept of supply elasticity of factors the same phenomena can be described and analyzed as good as with that highly modern theory, the difference is merely a matter of exposition.

Table 2 Summary of estimates from 1940–65

Period (20 years)	*Supply Elasticity*		*Elasticity of Expectation (b)*
	on short run (a_1b)	*on long run* (a_1)	
1940–1960	0.066	0.641	0.103
1941–1961	0.094	0.491	0.191
1942–1962	0.123	0.407	0.302
1943–1963	0.133	0.376	0.353
1944–1964	0.138	0.354	0.390
1945–1965	0.150	0.358	0.418

The estimates of (a_1b) and (b) for the years before 1940 did not significantly differ from zero, see Table 1.

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