Productivity measurement and supply analysis in agriculture

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Summary

Supply analysis is an important part of economic analysis, but there still are some inconsistencies and difficulties in the conventional type of analysis. These problems are to overcome by using a clear definition of agriculture and the "net value added concept" as defined in Fig. 1. A consequent application of these concepts leads to a new formulation of the supply relationship in agriculture. This formula has been used in a statistical study of Dutch agriculture, providing some reliable estimates of short and long run supply elasticities and of technical progress in agriculture, which enabled us to test some hypotheses about agricultural supply in The Netherlands.

1. Introduction

About ten years ago a famous american economist wrote: ". . . I do know that policy decisions and the growing emphasis on price policy research are going to force some agricultural economists to come up with some reliable and useful estimates of supply relations and elasticities in agriculture . . ." (COCHRANE, 1955) and it proved he was right. The research economist still finds some difficulties and inconsistencies applying the usual concepts of aggregate supply and technological advance. These problems are to overcome by using a clear definition for agriculture and the "net value added concept" as I shall try to show.

2. The aggregation problem

Supply of agriculture, as COCHRANE (1955) defined it, seems to be a simple case: "The aggregate supply relation for the nation at the farm level is simply the sommation of individual farm supply relations". In agriculture a firm usually produces more than just one product. "Thus the supply relation for multiple entreprice firm must describe how the aggregate of commodities produced and offered for sale varies as the prices of these commodities vary. In this context the variable, price, converts into an average, or level of prices to deal with several prices and the variable quantity converts into an index number of quantity, to deal with several different commodities". A difficulty to deal with is that the total of products offered for sale does not equal the final output of agriculture for there are always sales from one farmer to another. A correction for these interfarm sales is therefore necessary, in order to arrive at final output of agriculture.

Received for publication: 6th January, 1966.

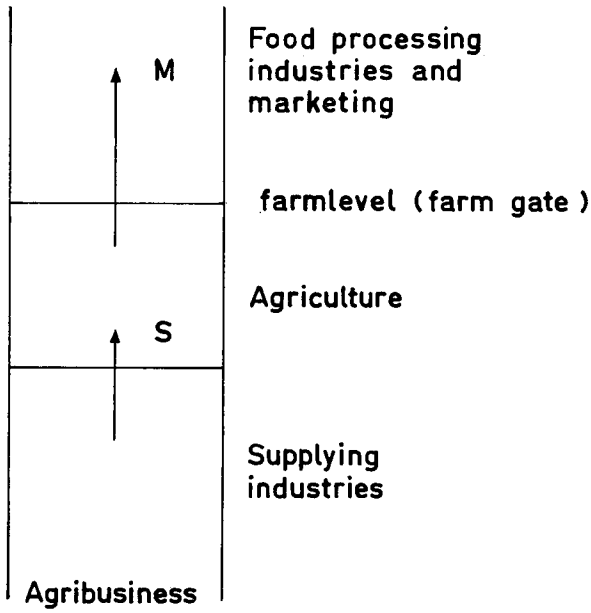

Fig. 1. A simple picture of agriculture as a part of agribusiness. The breadth of the column denotes the type of products, the length denotes the stage of production. S is the value of the supplied means of production (incl. depreciation) and M is the value of final product of agriculture. Net value added of agriculture is $M - S$. In American, Danish, Dutch, English and German agriculture S is about 50 % of M.

It is almost always the relation between this final output of agriculture and the price level of agricultural products what one has in mind speaking about the supply relation of agriculture. In my opinion, however, it is very doubtful that this relationship describes accurately the supply behaviour of agriculture for that final product is not only the output of agriculture but also of the industries supplying to agriculture (fertilizer, oil, machines, electricity etc.). In other words it is not the supply relation of agriculture what we have in focus now but the supply relation of the agribusiness up the farm gate. Here appears the necessity of a clear definition of agriculture.

In Fig. 1 we have a simple picture of agriculture as a part of "agribusiness". From this figure it follows how the proper supply relationship of agriculture has to look like. The *quantity* in this relationship ought to be the quantity agriculture itself is producing, that is adding to the production of food. This is the net product of agriculture or the difference between final output and all supplied means of production (including depreciation of buildings and machinery). This net product (N) is in other words the quantity-component of net value added of agriculture.

The *price* on the other hand in the supply relationship is the net price (P_n). This is margin between the price-level of final product and the supplied means of production or in other words the price-component of net value added of agriculture. To my opinion the supply relationship is in principle $N = f_1 (P_n)$.

Net product in this formula is produced with a certain quantity of factor input (F), the total of labour, capital (source of interest) and land. Without technical change net product will vary (besides influences of weather and diseases) by variations in factor input. This includes that the supply elasticity of agriculture depends on the limits set on to variation in factor input.

When the factors of production are not very mobile we can expect a small margin of variation in factor input and thus a low supply elasticity of factors; and reversed a high supply elasticity of factors when the factors of production are highly mobile. This implies that supply elasticity of agriculture is determined by the supply elasticity of the factors of production in agriculture.

3. Technical progress in agriculture

The role of technological advance has been ignored, or assumed away, to this point in order to conceptualize the various supply relations. But to ignore the role of technological advance, is to ignore the principal way in which the final output of agriculture has expanded in this century. This technological advance appears in improvement of the relation of "input" and "output" or in other words in a shift of the production function.

How does this production function looks like? The answer seems to be very simple. The production function of agriculture is the functional relationship between final output and total input of agriculture. In my opinion again, this answer is not wholly correct. Here too we have to use the "value added concept", then the production function of agriculture is $N = f_2 (F)$. Production is any activity that does increase the total amount of "utility". This activity is performed by the (original) factors of production. The quantity of this means of production can be measured by F (factor input). The result of production is a quantity of "utility". This quantity can be measured as net product N. (The value of it is "net value added" of agriculture, or agricultural income at factor cost). The production function then must be the relationship between that quantity of factors (F) and that quantity of utility (N).

Technological progress in agriculture appears in an improvement of the relationship between net product and factor input (HORRING and VAN DEN NOORT, 1963). It is possible, but not necessary of course, to complicate this picture in writing $N = f_3$ (Labour, Capital). In this case technical progress appears as a shift of this function, which can be measured by the well-known Solow-method (SOLOW, 1957). The result, however, is the same.

The change in the relation between net product and factor input is called "net (total) productivity", it gives an index of technological advance (incl. the influence of random factors as weather). This index differs from the index of total productivity (relation between final output and total input). This is a frequently used index, but it gives an underestimate of the growth in technological advance (HORRING, 1962). Even in the case we try to ascertain the supply relation for the agribusiness up to the farm gate we cannot use the index of final output/total input as a measure of technical progress. For it is possible that this relationship is not changing at all while there can be considerable technical advance in the production column namely in the supplying industries. Technical advance in the supplying industries implies that the same quantity of inputs for agriculture (fertilizers, pesticides, oil, buildings, machinery etc.) can be produced with less labour and/or capital. Total input of agriculture, however, does not alter nor does final output. Although there can be a considerable improvement in food production (up to farm level) the index of total productivity does not registrate a single change. A correct measure for technical progress in the production column (up to farm level) would be the relation between final output and factor input of agriculture and supplying industries together. Here too the "value added concept" leads to the right answer.

4. Correlation between price trends and technical progress

Appliance of these concepts would yield a very simple formula for the supply relation of agriculture: $N = f_4 (P_n , A)$.
In this function N = net product, P_n = net price, A = index of technical advance. Technical advance measured here either as net total productivity (index of the relation of net product and factor input) or as $A (t)$-index of technical progress defined by Solow.
A simple regression analysis would further have provided us with the relevant supply elasticity of agriculture when there was not a disturbing difficulty: there is some correlation between the "explaining" variables P_n and A. For SCHUMPETEH (1961) and COCHRANE (1959) have correctly pointed out that technical progress depends in some degree on the price-level and price-uncertainty. Indices of productivity in agriculture in Canada, Denmark, Germany, The Netherlands and the United States show that during the great depression of the 1930th technical advance in agriculture slowed down, probable caused by economic factors as low prices and uncertainty, and showed further a considerable improvement when prices went up and got stabilized (VAN DEN NOORT, 1965).
A solution of this "interaction problem" can be reached by ascertaining the regression equation of $N^c = f_5 (P_n)$ in stead of $N = f_4 (P_n , A)$. N^c is net product of agriculture, corrected for technical progress and weather influences. This correction is performed by dividing the index of net production by the index of technical progress; apparently the index of N^c is equivalent to the index of factor input.

5. Time lags and "normal prices"

Up to here I have ignored the factor time in the supply relation. It is well known that the production of agricultural goods saled 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. Probable there are some time lags. It is a useful hypothesis to expect that farmers have an idea of "normal prices" as NERLOVE (1958) pointed out.

6. Appliance of the concepts of Dutch agriculture

I'll try now to apply the concepts to Dutch agriculture in the period 1923—1962 in order to test three hypothesis:

1. The supply relation is "backward sloping" or in other words the supply elasticity of agriculture is negative.
2. Supply of agriculture is extremely inelastic.
3. There is a considerable difference in the elasticity of supply of agriculture on short run and on long run, according to the supply elasticity of agricultural labour.

The period is investigated into two parts 1923—1939 and 1949—1962. This division was necessary for two reasons. First, the statistics of the pre-war period differ from the statistics of the post-war, period, and second, the war and its aftermath formed a tremendous interruption and created a rather unusual situation in Dutch agriculture for which no reliable statistics are available.

6.1. The pre-war period

The statistical data on prices and production for this period are given per crop year. The production saled in crop year t started in crop year $(t-1)$. The prices that were fully known at this start were the prices in earlier crop years $(t-2)$, $(t-3)$ etc. On basis of these prices a production was planned for example according to the following formula $N_t^e = f\,(P_{t-2})$.

It is possible to refine this hypothesis by applying Nerlove's method, getting the following equation:

$$N_t^e = a_o\,\beta + a_1\,\beta\,P_{t-2} + (1-\beta)\,N_{t-1}^e$$

in which β = coefficient of price expectation. Table 1 gives the necessary statistical information.

Using the statistics of Table 1 we found the following regression equation:

$$N_t^e = 43{,}97 + \underset{(0.024)}{0.093\,P_{t-2}} + \underset{(0.146)}{0.481\,N_{t-1}^e} \qquad R^2 = 0.87$$

From this equation it follows that the average supply elasticity was on short run $+0.08$ and on long run $+0.15$.

Table 1. Statistical data for Dutch agriculture [1], 1923—1939 (VAN DEN NOORT, 1965)

Crop year	*Net production* [2]	*Factor input* [3]	*Net total productivity* [4]	*A(t)-index* [5]	*Net price* [6] *1924/1925—1928/1929 = 1.00*
1923/24	100.0	100.0	100.0	—	1.021
1924/25	113.8	100.1	113.7	100.0	1.007
1925/26	115.3	101.1	114.7	102.0	1.003
1926/27	126.8	102.3	123.9	109.1	0.896
1927/28	109.1	103.2	105.7	92.8	1.006
1928/29	121.3	103.3	117.4	103.0	0.996
1929/30	126.7	105.6	120.0	105.2	0.852
1930/31	140.6	103.3	136.1	119.7	0.676
1931/32	150.5	102.3	147.1	130.1	0.471
1932/33	152.2	100.6	151.3	133.8	0.511
1933/34	143.6	96.6	148.7	129.2	0.642
1934/35	148.1	97.2	152.4	135.1	0.582
1935/36	141.0	97.2	145.1	128.6	0.622
1936/37	133.3	94.6	140.9	124.9	0.716
1937/38	135.2	94.7	142.8	126.3	0.794
1938/39	137.5	98.5	139.6	123.5	0.741

[1] Excl. horticulture.
[2] Weight period 1924/1925—1928/1929.
[3] Labour, land and capital, weight period 1924/1925—1928/1929.
[4] Net production per unit of factor input.
[5] $A(t)$-index of technical progress as defined by Solow (1957), figures for 1923/1924 are not available. Taking into account the difference in base-year the trend in the $A(t)$-index and the net total productivity index are practically the same.
[6] Price-component of net value added, measured in guilders of constant purchasing power.

Table 2. Statistical data for Dutch agriculture [1], 1949—1962 (VAN DEN NOORT, 1965)

Year	*Net production* [2]	*Factor input* [3]	*Net total productivity*	*A(t)-index* [4]	*Net price 1953 = 1.00*
1949	100.0	100.0	100.0	100.0	1.124
1950	104.7	99.8	104.9	105.1	1.084
1951	111.1	98.7	112.5	112.9	0.984
1952	114.6	97.3	117.8	118.1	1.024
1953	109.9	95.8	114.7	115.1	1.000
1954	113.6	94.7	120.0	120.5	1.009
1955	122.4	93.3	131.2	131.9	0.945
1956	111.8	92.1	121.3	122.0	1.010
1957	120.8	90.9	132.9	133.8	0.939
1958	124.3	88.8	139.8	141.0	0.867
1959	107.9	86.9	124.1	124.9	0.971
1960	144.6	85.7	167.1	170.1	0.848
1961	130.3	84.7	156.0	155.3	0.894
1962 [5]	130.7	80.9	161.6	—	0.840

[1] Incl. horticulture.
[2] Weight period 1953.
[3] Factor cost at constant 1953 prices.
[4] The trend in the $A(t)$-index (defined by Solow) and the net total productivity index are practically the same.
[5] Preliminary.

6.2. The post war period

For this period we have only a slight difference in method, i.e. the time lag is now only one calenderyear in stead of two crop years, see Table 2.
Using these data we found the following regression:

$$N_t^c = -3.651 + \underset{(2.659)}{6.519\, P_{t-1}} + \underset{(0.039)}{0.956\, N_{t-1}^c} \qquad R^2 = 0.99$$

From the figures of Table 2 and this equation it follows that the short run average supply elasticity was $+0.07$ and the long run elasticity $+1.58$.

6.3. Test of hypotheses

From the statistical estimates it follows that farmers do not react much to price changes on short run; on long run it can be otherwise. Do these measurements have a real economic meaning? In my opinion: yes. There is an important difference between the long run supply elasticity for the pre-war period, and the post-war period. This can be explained easily: in the pre-war period, opposite to the years after 1949, there was no real opportunity for farmers and farm labourers for unemployment went high, see Table 3. The supply elasticity of agricultural labour was therefore low in the pre-war period, but high in the years after 1949. This implies that we might expect a low long run supply elasticity for agricultural production in the pre-war period and a much higher elasticity in the period 1949 up to this moment. We arrive at the following conclusions:

1. There was no backward-sloping supply curve in Dutch agriculture for the supply elasticity was apparently positive.
2. Supply of agriculture was highly inelastic on short run, with average supply elasticity probable as high as ca. 0.1.
3. There is a difference between the short run and long run supply elasticity, depending on the opportunities for agricultural labour.

Table 3. Unemployment as percentages of labour force, 1921—1962 (C.B.S., 1959)

Year	*%*	*Year*	*%*	*Year*	*%*
1921	3.3	1931	3.5	1949	1.7
1922	4.5	1932	6.6	1950	2.1
1923	4.8	1933	11.3	1951	2.4
1924	4.0	1934	12.7	1952	3.6
1925	3.7	1935	13.6	1953	2.6
1926	3.3	1936	16.0	1954	1.8
1927	3.4	1937	17.3	1955	1.3
1928	2.7	1938	14.2	1956	0.9
1929	3.0	1939	12.6	1957	1.2
1930	3.5	1940	9.2	1958	2.4
				1959	1.8
				1960	1.2
				1961	0.9
				1962	0.8

With the appliance of the "net value added concept" (net production, net price, net productivity) we get a rather simple solution of some problems arising at the analysis of aggregate supply in agriculture. These problems do not only exist in The Netherlands, but also in other countries i.e. the United States (WORKING, 1957), testifying the following quotation, concerning the analysis of supply in post-war American agriculture: "This supply behaviour is bafflivg to us . . . We need more and better data and more powerful analysis to answer this question (WILCOX and COCHRANE, 1962). I hope my suggestions are useful to get such an answer.

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