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Output Elasticity and Returns to Scale in The Saudi Dairy Industry

Mohammad Hamid Abdallah*
Department of Economics, College of Admin. Sciences,
King Saud University, Riyadh, Saudi Arabia.

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Abstract. A Cobb-Douglas production function was estimated for the Dairy Industry in Saudi Arabia to determine the output elasticity and returns to scale in this industry. The results showed that dairy output is inelastic with respect to both capital and labor though it is relatively more elastic with respect to labor. This industry is found to exhibit increasing returns to scale. The most important conclusion is that labor productivity in this industry is higher compared to capital because the letter mentioned is heavily subsidized and hence it is over used. The second important conclusion is that economies of scale in this industry do exist and it is more efficient to use bigger size plants (to a certain extend) to benefit from the scale economies.

Introduction

The general purpose of this paper is to examine the relative response of dairy output to changes in labor and capital and to determine the relationship between output and factory size in the Saudi Dairy Industry (will be referred to hereafter as DI). Determination of these two economically and technically important production relations is very useful for both industrial public policy makers and private investors. DI, like all other industries in Saudi Arabia (will be referred to hereafter as SA), employs basically foreign labor and imports most of the capital and technology it needs. Unlike most developing countries which have surplus labor but deficient in financial resources needed to purchase capital and technology, SA is labor deficient but has surplus financial capacity enabling it to purchase the capital and technology it requires.

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SA economy is generally based upon the market system. However, the government subsidies all kinds of industrial and agricultural investments to encourage local production in order to diversity its national income which is heavily dependent upon oil revenues. The DI is chosen for this study because it is one of the most growing and expanding among the soft industries in SA [1].

One of the best methods to achieve the objectives of this research which are the determination of output elasticity and returns to scale in DI of SA, is regression analysis (OLS). The Cobb-Douglas production function is a suitable model for the purpose of this study because we can readily and directly get output elasticity for each input which are the exponents of each input and returns to scale which is the sum of those exponents. Moreover, the author found in an earlier study comparing different production functions for this industry, that this function is fitting and all its coefficients are significant at 5% level and their signs are consistent with received economic theory [2].

The Model

The model to be estimated is the standard two variable Cobb-Douglas production function:

$$Y = AL^a . K^b$$

The logarithmic form of this model is

$$\text{Log } Y = \text{Log } A + a \text{ Log } L + b \text{ Log } K.$$

Where:
Y is output, L is the quantity of labor and K is the amount of capital. A, a and b are the parameters to be estimated.

Needless to say, labor and capital are not the only inputs in dairy production. However, the rest of the inputs are assumed to be constant. That is not just to simplify the analysis but it is more or less a realistic assumption in this industry. For example, one ton of milk will give the same amount of butter or yoghurt irrespective of factory size or otherwise.

Data

Out of 50 dairy plants in SA in 1413, 37(74%) were chosen for this study because they produce only dairy products. Some of the plants are producing multiple products together with the dairy products such as meat, vegetables processing and juices. Those plants are excluded to ensure the homogeneity of output as much as possible. A few (about 3 plants) were excluded because of their odd figures (either too low or too high) to avoid, as much as possible, heteroscidasticity and other disturbing statistical problems, which may arise due to their presence.

Cross-sectional secondary data on dairy output, labor and capital for each of the 37 dairy factories chosen for this study, were collected from the official Annual Report of Production Factories in SA for 1991 which is published annually by the Ministry of Industry and Electricity, Riyadh, SA [3].

Output and inputs data used for estimating any production function usually suffer from lack of homogeneity. To minimize this problem, in this study, we used tons of milk equivalent for each dairy product. The weighted total production for all types of dairy products in each factory is considered as its total dairy output. Labor is relatively the least problematic in this respect. So, we used the number of workers directly involved in the dairy production process in each factory as the best proxy measure for this variable. Capital is very cumbersome and controversial input not only with respect to lack of homogeneity and difficulty of aggregation, but also with respect to lack of divisibility [4,5]. That is why different ways of measuring capital were suggested such as electricity, fuel consumption [6], machine-hours [7], depreciation, etc. However, one of the most commonly used proxy measure for this input and the only available one for the author is the value of the annual depreciation of capital in each factory (Table 1).

Results

Using the TSP computer programs, the estimated Cobb-Douglas production function for the DI in SA is found to be as follows:

$$Y = 18.19\, L^{0.85}.\, K^{0.35}$$

$$\underset{}{\text{Log } Y - \text{Log } \underset{(4.00)}{18.19} + \underset{(11.14)}{0.85 \text{ Log } L} + \underset{(6.73)}{0.35 \text{ Log } K}}$$

$$R = 97.95\%,\ F = 861.95 \text{ and Durbin} - \text{Watson} = 1.60$$

From the above statistical information and tests it is evident that the intercept and the coefficients of both labor and capital are all significant at 5% level and their signs are all consistent with economic theory. R^2 is very high (97.98%) and so, the

Table 1. Labour (L), Capital (K), and Output (Y).

Obs	L No. of Workers	K Annual Depreciation (Thousand SR)	Y Tons of Milk Equivalent
1	75.00	1154.00	13600.00
2	88.00	5210.00	21717.00
3	80.00	530.00	3000.00
4	26.00	520.00	6066.00
5	34.00	1760.00	3900.00
6	7.00	64.00	345.00
7	61.00	1460.00	10938.00
8	24.00	1300.00	4964.00
9	23.00	2988.00	3940.00
10	90.00	2920.00	15250.00
11	72.00	2000.00	7050.00
12	68.00	280.00	735.00
13	35.00	1260.00	4500.00
14	82.00	4200.00	12022.00
15	20.00	381.00	2560.00
16	35.00	650.00	2870.00
17	32.00	554.00	4392.00
18	44.00	1330.00	4500.00
19	338.00	18925.00	90000.00
20	18.00	1590.00	10950.00
21	23.00	634.00	2500.00
22	7.00	400.00	2000.00
23	28.00	1830.00	4500.00
24	18.00	800.00	2997.00
25	271.00	5967.00	50778.00
26	40.00	690.00	2975.00
27	10.00	242.00	1200.00
28	32.00	770.00	1500.00
29	15.00	19.00	370.00
30	13.00	607.00	840.00
31	26.00	250.00	1500.00
32	26.00	270.00	1200.00
33	44.00	1605.00	5100.00
34	50.00	540.00	1550.00
35	75.00	1660.00	10775.00
36	22.00	410.00	950.00
37	27.00	1090.00	4100.00

Source: (a) Basic data from the Ministry of Industry and Electricity. *Annual Report of Productive Factories*, 1991. [3]

(b) The author calculated the annual depreciation for capital and milk equivalent for output.

regression equation fits the data very well, and that there is no model specification problem. Tests for heteroscidasticity and multi-collinearity were conducted and none of them was significant. Durbin-Watson test, which is not important in cross-sectional data (it is concerned with serial auto-correlation) is 1.6 which is greater than both d_L (1.36) and d_U (1.59) at 5% level.

$$MPPL = 15.46\, L^{-0.15} K^{0.35} = \frac{15.46\, K^{0.35}}{L^{0.15}}$$

$$MPPK = 6.37\, L^{.85} K^{-0.65} = \frac{6.37\, L^{.85}}{K^{0.65}}$$

The second order condition is satisfied since the rate of change of MPP is decreasing for both capital and labor which is consistant with economic theory:

$$APPL = \frac{Y}{L} = \frac{18.19\, L^{0.85} K^{0.35}}{L} = \frac{18.19\, K^{0.35}}{L^{0.15}}$$

$$APPK = \frac{Y}{K} = \frac{18.19\, L^{0.85} K^{0.35}}{K} = \frac{18.19\, L^{0.85}}{K^{0.65}}$$

The average physical product (APP) for both inputs is indirectly related to the amount of input. That means this industry is working in stage II which is the relevant or the economically rational stage of production.

From the above, it is evident that the estimated model fits the DI data from both statistical and economic theory points of view. Output is inelastic with respect to both labor (0.85) and capital (0.35). However, it responds to changes in labor more than to changes in capital. A one percent increase in labor, the amount of capital held constant, may increase dairy output by 0.85% whereas a one percent increase in capital, with no change in the labor employed may increase output by 0.35%. This may reflect that the productivity of labor is relatively higher in this industry than that of capital.

As for returns to scale, this industry exhibits increasing returns to scale because the sum of labor and capital exponents is greater than one (0.85 + 0.35 = 1.20). A one percent increas in both labor and capital may increase output in this industry by 1.2%.

Empirical Analysis

The estimated Cobb-Douglas function is used to find the expected (fitted) output (Table 2), MPPL and APPL (Table 3), MPPK and APPK (Table 4). Out of the 37 plants chosen for this study, the actual output of 13 of them only is higher than the fitted one and the rest (24) are producing less than their efficient frontier measured by fitted y (Table 2). A careful look at this Table shows that as the plant size increases (measured by labor and capital) output increases too.

Both the average physical product (which measures productivity of inputs) and managerial physical product (which measures the rate of change in output in response to changes in output) are by far higher for labor compared to capital (Tables 3 and 4). This reflects the higher productivity and output elasticity of labor as compared to capital, which could be due to the high government subsidy for purchased capital which may have tempted investors in this industry (and for that matter, all other industries in SA) to over use capital. So, this industry could employ more labor and keep the existing stock of capital as it is now and at the same time increase both output and productivity of capital.

Policy Implications

1– The results of this study imply for the public industrial policy makers that subsidising capital in the dairy industry had tempted the private sector to overuse this input.
2– Studies should be carried to find the optimum subsidy which will make the use of capital input at the optimum level.
3– As for the private sector, the policy implications is to add more labor to the existing capital stock to increase output and at the same time increase productivity of capital.
4– The bigger size plants are more economic and more efficient than smaller plants in this industry.

Summary and Conclusion

This study is conducted to examine the returns to scale and output elasticity in the Dairy Industry (DI) in Saudi Arabia (SA). A Cobb-Douglas function is used to estimate the production function of this industry. It is found that this industry exhibits increasing returns to scale and its output is inelastic with respect to both labor (0.85) and capital (0.35), *i.e.* increasing labor may increase production more

Table 2. Actual and Fitted Output Residuals (Actual-Fitted) and Scattered Diagram.

Residual Flat	Obs	Residual	Actual	Fitted
: : : *	1	4853.33	13600.0	9246.67
: : : *	2	3663.74	21717.0	13053.3
: * :	3	-166.96	3000.00	3166.97
: : : *	4	3304.51	6088.00	2733.49
: * : :	5	-1525.13	3900.00	5425.13
: * :	6	-82.42	345.00	427.42
: : : *	7	2580.96	10938.0	8357.05
: : * :	8	1350.53	4964.00	3513.47
: * : :	9	-746.06	3940.00	4666.08
: : * :	10	304.33	15250.0	14945.7
* : : :	11	-3731.37	7050.00	10761.4
* : : :	12	-4010.15	785.00	4745.15
: * : :	13	-431.69	4500.00	4931.69
* : : :	14	-3707.85	12022.0	15729.8
: * : :	15	-429.40	1560.00	1969.40
: * : :	16	-1017.59	2870.00	3387.59
: : * :	17	991.86	4392.00	3400.13
: * : :	18	-1615.92	4500.00	6113.92
: * : :	19	-586.12	90000.0	90566.1
: : : *	20	7911.59	10950.0	3038.41
: * :	21	-191.86	2500.00	2691.67
: : * :	22	1174.14	2000.00	825.86
: * :	23	-161.00	4500.00	4661.00
: : * :	24	1199.28	2997.00	1797.72
: : * :	25	1239.06	50778.0	49536.9
: * : :	26	-1476.77	2975.00	4451.77
: : * :	27	265.09	1200.00	934.91
* : :	28	-2327.23	1500.00	3827.23
: * :	29	-159.65	370.00	529.65
: * : :	30	-767.90	840.00	1627.90
: * : :	31	-639.31	1500.00	2139.31
: * : :	32	-999.31	1200.00	2199.31
: * : :	33	-1441.18	5100.00	6541.18
: * : :	34	-1638.31	1550.00	3168.31
: * :	35	-101.46	10775.0	10876.5
: * : :	36	-1265.78	950.00	2215.78
: : * :	37	349.29	4100.00	3750.70

Table 3. Marginal and Average Physical Products of Labour.

Obs	L	MPL	APL
1	7.00	173.39	203.00
2	7.00	173.39	203.00
3	10.00	164.60	192.71
4	13.00	158.41	185.47
5	13.00	156.41	185.47
6	15.00	158.14	161.64
7	18.00	151.07	176.87
8	20.00	148.76	174.18
9	22.00	146.71	171.77
10	23.00	145.76	170.66
11	23.00	145.76	170.66
12	24.00	144.66	169.60
13	26.00	143.18	167.63
14	26.00	143.18	167.63
15	26.00	143.18	167.63
16	17.00	142.39	166.71
17	28.00	141.64	165.83
18	30.00	140.22	164.17
19	30.00	140.22	164.17
20	32.00	138.91	162.66
21	32.00	138.91	162.63
22	34.00	137.68	161.20
23	35.00	137.10	160.52
24	35.00	137.10	160.52
25	40.00	134.46	157.42
26	44.00	132.60	155.25
27	44.00	132.60	155.25
28	61.00	128.43	146.62
29	63.00	125.83	147.33
30	72.00	123.41	144.49
31	75.00	122.67	145.63
32	75.00	122.67	143.63
33	82.00	121.09	141.77
34	86.00	119.65	140.32
35	90.00	119.45	139.66
36	271.00	101.71	119.06
37	338.00	96.46	115.30

Table 4. Marginal and Average Physical Products of Capital.

Obs	K	MPK	APK
1	19.00	28.66	79.62
2	64.00	13.15	56.58
3	242.00	5.61	15.60
4	250.00	5.49	15.28
5	270.00	5.23	14.55
6	280.00	5.11	14.21
7	381.00	4.19	11.87
8	400.00	4.06	11.31
9	410.00	4.00	11.13
10	520.00	3.43	9.56
11	530.00	3.59	9.44
12	540.00	3.35	9.33
13	554.00	3.30	9.16
14	607.00	3.11	8.66
15	634.00	3.02	6.42
16	650.00	2.96	6.28
17	690.00	2.86	7.97
18	770.00	2.67	7.43
19	800.00	2.60	7.25
20	1090.00	2.14	5.95
21	1184.00	2.03	5.64
22	1260.00	1.95	5.42
23	1300.00	1.91	5.31
24	1330.00	1.88	5.24
25	1460.00	1.77	4.93
26	1590.00	1.68	4.67
27	1605.00	1.67	4.64
28	1760.00	1.57	4.36
29	1830.00	1.53	4.27
30	1860.00	1.52	4.22
31	2000.00	1.45	4.03
32	2910.00	1.13	3.16
33	2968.00	1.12	3.13
34	4200.00	0.90	2.50
35	5210.00	0.76	2.18
36	5967.00	0.72	2.00
37	18925.00	0.34	0.95

than increasing capital. This may be due to the high subsidization of capital which led to its over utilization in this industry.

These findings are important for both policy makers and private investors in their current and future decisions. Larger sizes of dairy plants are better because they benefit from increasing returns to scale and hence increasing economies of size. In other words, it is more efficient to use bigger plant sizes in this industry. This study also shows the importance of finding the optimum capital subsidy in this industry, and even other industries in SA. Optimum subsidy may reduce the use of capital to an optimum level.

Shortcomings of The Study

1– The results are as good as the data used for this study.
2– The known problems of the Cobb-Douglas production function and its restrictive assumptions.
3– Although we tried our best to homogenize the data as much as possible we cannot claim that we are 100% successful.
4– Use of annual depreciation of capital to measure capital input, is a criticisable proxy measure. However, it was the only available one of this study.

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مرونة الإنتاج وعائدات الحجم في صناعة الألبان بالمملكة العربية السعودية

محمد حامد عبدالله

أستاذ مشارك، قسم الاقتصاد، كلية العلوم الإدارية، جامعة الملك سعود، الرياض، المملكة العربية السعودية

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ملخص البحث. تم تقدير دالة كوب دوكلاس لصناعة الألبان بالمملكة العربية السعودية لتحديد مرونة الإنتاج وعائدات الحجم في هذه الصناعة. وقد أوضحت النتائج أن إنتاج الألبان غير مرن بالنسبة للعمل ورأس المال إلا أنه نسبيًا أكثر مرونةً بالنسبة للعمل والذي هو أيضًا أكثر إنتاجية في هذه الصناعة. أي أن هذه الصناعة تتمتع بمزايا اقتصاديات الحجم الكبير. وقد يكون سبب انخفاض إنتاجية رأس المال مقاسة بإنتاجيته الحدية هو أنه مستخدم في هذه الصناعة بقدر أكبر مما هو أمثل والذي بدوره قد يكون بسبب الدعم الكبير لهذا العامل الإنتاجي. كما اتضح أيضًا أن إنتاج هذه الصناعة يتزايد مع تزايد حجم المصنع مقاسًا بزيادة عنصري العمل ورأس المال في الوقت ذاته.