The Cost Of Scale Inefficiency In The Canadian Brewing Industry: A Multi Product Cost Function Approach

Dr. Manolis D. Tsiritakis, College of Business, Mississippi State University.
Dr. Charles A. Campbell, College of Business, Mississippi State University.
Dr. Andreas G. Merikas, College of Business, Mississippi State University.

Abstract

The study examines economies of scale for the Canadian beer industry using multi-product cost functions using micro data. The results reflect the effects of product mix, industry regulation, and interprovincial trade prohibitions. With the present mix of products 10 plants could supply the needed quantity of beer at less expense than the current configuration of 25 plants. The cost of regulation is estimated to be approximately 6.5% above the optimal plant cost.

I. Introduction

A number of studies in the past few years have examined industry specific economies of scale using multi-product cost functions. This study uses a rather unique micro data set for the Canadian beer industry and examines not only the effect of product mix on the degree of economies of scale but also the effect of an atypical sort of industry regulation, interprovincial trade prohibition.

The next section of the paper examines the theoretical framework of the model and develops the model specifications. Section III describes the nature of the data set as well as limitations to the data. Technical considerations that are important in examining the multi-product firm economies of the Canadian brewing industry are presented in Section IV. These considerations allow for a clearer interpretation of the econometric results which follow. Estimates for the multi-product minimum efficient scale (MES) from 4 statistical procedures using quadratic multi-product cost functions are presented in Section V. Finally, Section VI considers the implications of the study.

II. Theoretical Framework and Model Specification

A producer is called socially efficient if output corresponds to the long run competitive equilibrium (Fare, Grosskophf, and Lovell, 1985). Such an equilibrium corresponds to the "technically optimal scale" advanced by Frisch (1965) and the "M-locus" of Baumol, Panzar, and Willig (1982). Scale inefficiency may result in a suboptimal level of output and therefore a less than socially optimal equilibrium even though the producer minimizes costs.

Scale inefficiency can be measured by estimating a cost function. In the case of an industry such as brewing where multiple products (drought beer, canned beer, and bottled beer) are distinguished by significant differences in production costs, a multi-product cost function is appropriate. This method provides an estimate of the degree of economies of scale at a point along a ray in the product space. Such estimates are not constrained to the M-locus which is defined as the set of all output vectors that minimize ray average costs along these rays.

The multi-product cost function is the unique dual of a general production function (or transformation function)

$$Q = f(y_1, \ldots, y_{nj}\ x_1, \ldots, x_m) \qquad (1)$$

where Q is a set that defines all patterns of outputs and inputs, the y_i are levels of outputs, and the x_i are the levels of inputs for n outputs and m inputs. The general form of the multi-product cost function is then

$$C = (y_1, \ldots, y_{nj}\ w_1, \ldots, w_m) \qquad (2)$$

for n outputs and m inputs, where the w_i are prices of inputs and the y_i are levels of the outputs.

The normal functional form used in empirical work is linear in parameters. They are second order Taylor series approximations to an arbitrary cost function. The approximations preserve the values of the first and second derivatives of the true function in the neighborhood of the point where the approximations are made. It is possible to use other specific forms that are explicitly constructed to be flexible but which are not viewed as reasonable approximations to families of cost functions. The first option is followed here as it preserves generality and allows a closer approximation to the true underlying function. Such a cost function has the general form:

$$C(y,w) = h(y_1,\ldots,y_n) \quad g(w_1,\ldots,w_{mj} \; T) \tag{3}$$

where h(.) could be approximated by a second order Taylor expansion in powers of y_i and g(w) is a linearly homogeneous concave and non-decreasing function with T accounting for factor augmenting non Hicks neutral technical change. If it is assumed that in any year input prices do not vary with size or location, that all plants face the same input price vector, the function, g(w), need not be specified. Input ratios are then independent of output levels and C(y,w) is compressed to:

$$C(y) = h(y_1,\ldots,y_n) \quad C \tag{4}$$

Where C(y) is approximated by:

$$C(y) = A_0 + \sum_{i=1}^{n} a_i y_i + 1/2 \sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij} y_i y_j \tag{5}$$

Here C(y) is the quadratic cost function whose dual is explicitly available and where a_0 represents total fixed costs (see Fuss and McFadden, 1978; and Lau, 1973). The function is then estimated in [(n+1)(n+2)]/2 parameters.

For the Canadian Brewing industry there are three outputs and three product sets. Letting y_1, y_2, and y_3 represent the output of bottled, draught, and canned beer respectively, the production combinations in the sample are {1}, {1,2}, and {1,2,3}. Setting the dummy variable D_i equal to the value of unity whenever positive amounts of product i are produced and zero otherwise, equation (5) is replaced by

$$C(y) = A_0 + \sum_{i=2}^{3} A_{0i} LD_i + \sum_{i=1}^{3} a_i y_i + (1/2) \sum_{i=1}^{3} \sum_{j=1}^{3} a_{ij} y_i y_j$$

$$S_n(y) = A_0 + \sum_{i=2}^{3} a_{0i} D_i + \sum_{i=1}^{3} a_i y_i + (1/2) \sum_{i=1}^{3} \sum_{j=1}^{3} a_{ij} y_i y_j \tag{6}$$

and the estimate of a_0 is then an estimate of product specific fixed-costs for y_1 and a_{02} and a_{03} are incremental fixed costs for y_2 and y_3, respectively. The product-set-specific costs for y_1 and y_2 are estimated by $a_0 + a_{02}$. Fixed costs for the N product set are estimated by $a_0 + a_{02} + a_{03}$.

For the cost function (6), the ray returns to scale $S_n(Y)$ at y is given at the point y by:

$$\sum_{i=1}^{3} a_i y_i + \sum_{i=1}^{3} \sum_{j=1}^{3} a_{ij} y_i y_j \tag{7}$$

$$\text{if} \quad A_0 + \sum_{i=2}^{3} a_{0i} > (1/2) \sum_{i=1}^{3} \sum_{j=1}^{3} a_{ij} y_i y_j \tag{8}$$

then $S_n(y) > 1$ and economies of scale are present at the vector y where y the function is evaluated. For all vectors of the same ray, $S_n(y)$ corresponds to a U-shaped or L-shaped scale curve depending on the relation in (8). Each value of $S_n(y)$ will, however, reflect the degree of economies of scale for a specific point y on the ray.

Finally, it should be noted that weak cost complementaries would exist if:

$$\frac{\partial^2 C}{\partial y_i \quad y_j} = a_{ij} \leq 0 \tag{9}$$

III. Data and Data Limitations

The data used to estimate the quadratic cost function cover the operation of 25 plants during 5 years (1978-1982). The sample therefore includes 125 observations. All of the plants produced bottled beer, 22 plants produced draught beer, and 6 plants produced canned beer. One of the plants producing canned beer only produced canned beer for the last two years of the period. The data was constructed from raw firm-specific data originally collected by M. A. Goldberg and C. C. Edkel for their 1982 study of costs incurred by a brewing plant allocated to brewing, packaging and distribution activities. Distribution costs are not included because the percentage of transportation provided by the firm varies by province and plant. The brewing and packaging activities together constituted the production costs for beer products. The primary production factors are labor, capital, fuel, materials and managerial services.

The measure of total cost (TPC) is calculated for each plant to include: (1) total labor costs; (2) total material costs for brewing; (3) total material packaging costs; (4) total fuel costs (not including electricity costs); and (5) depreciation as a historical approximation of capital costs.

Electricity costs are excluded from total fuel costs because of a lack of reporting by some firms. However, since electricity costs generally constitute less than 2% of total production costs, the expected bias that results should be minimal.

Capital costs are not available in the form of a real measure of plant and equipment replacement costs, therefore accounting depreciation is used as an approximation.

Total production costs are deflated by the Consumer Price Index with the resulting production costs in thousands of 1982 Canadian dollars.

Output variables are in thousands of hectoliters (hls) shipped from the breweries in the form of bottled, canned, and draught (kegs) beer. Total beer output brewed in any given year exceeds shipped outputs slightly but shipped outputs tend to represent approximately 99% of brewed beer.

IV. Technical Considerations

It is assumed that firms in this sample minimize the cost of production subject to a homothetic production function. This is an important assumption since this type of function implies that input ratios are independent of output scale. This means that changes in relative input intensities cannot be estimated. Additionally, the assumption implies that input demand elasticities with respect to output are equal and independent of input prices. As a result, one cannot readily obtain an estimate of the effect of input prices on industry structure. The assumption is made because the nature of the study and the advantages as far as tractability is concerned outweigh the bias created by the assumption.

The purpose of the study is to estimate scale inefficiency in the Canadian brewing industry. The focus is upon dealing more clearly with the effects of outputs on costs. It is therefore reasonable to simplify the analysis by ignoring the effect of input prices on costs.

For the industry, in the period studied (1978-1982), there are no significant differences across firms in the movement of input prices. The cost of the homotheticity assumption created by the bias in the estimate of economies of scale is therefore small. Fuss and Gupta (1981) have demonstrated this for Canadian manufacturing during a similar period. There use of a non-homothetic translog cost function (single product) shows that, because of Engel aggregation conditions, the term with input prices vanishes since cost shares add to unity. This is true when input prices are equal across firms and grow at an equal rate (as with inflation). In such a case homotheticity does not create any bias. If the sample population is not perfectly consistent with the assumption there will be some bias. Denny, Fuss, and Waverman (1979) indicate that this bias for Canadian manufacturing is 0.125%.

The major inputs in Canadian brewing are sold in government controlled markets and labor is unionized. Shifts in the long run average cost curve due to changing input prices across time and due to neutral technical change can therefore be captured using dummy variable to represent time.

The inclusion of depreciation as part of total costs might bias total production costs upwards for newer plants if it is not straightline depreciation. Newer plants in this sample are the larger ones which will tend to bias the scale results downward so that a plant size which is estimated to have small diseconomies of scale might, in fact, be experiencing economies of scale. Depreciation of capital costs are, on average, 8% higher for larger plants. As output rises, total costs will, therefore, go up somewhat faster because greater output is produced by larger plants whose costs are higher due to depreciation costs. The absence of real capital costs and input prices and the inclusion of depreciation could bias estimates but any such bias should be downward. The literature does tend to support the assumption of multiplicative separable cost functions and the focusing on output and average costs (Fuss and Gupta (1981).

Transportation costs are excluded as a matter of feasibility following the logic of Goldberg and Eckel (1982) who indicate that since production costs are similar across Canada, and because of variations in provincially regulated promotion and distribution regulations, it is difficult to develop any meaningful distribution or promotion cost comparisons. This leads to the conclusion that production costs should provide the most consistent set of measures across provinces.

Test of Hypothesis

The underlying model is based on the behavioral postulate of profit maximization. In an industry where prices are heavily influenced by provincial governments, it is assumed that firms are price takers and therefore, minimize costs in order to maximize profits. The problem of X-inefficiency is assumed away and the cost minimizing firm is assumed to be both technically and allocatively efficient. The only inefficiency to be observed is assumed to be scale inefficiency. It is also assumed that interprovincial trade prohibitions cause cost minimizing firms to operate scale inefficient plants since they must serve very small markets relative to the MES capacity of a brewer. This implies that the Canadian brewing industry operates conditionally optimal with respect to current regulations.

Finally, while it is possible that the over time the scale curve may shift due to Hicks neutral technological change or that the newer and larger plants may be more capital intensive than older plants, such effects are likely to be minimal in such a short time in a technologically mature industry.

V. Estimation Procedure and Results

The function is first estimated using OLS and tests for multicollinearity are performed. The condition indices and the variance proportions indicate a multicollinearity problem which is possibly due to the structure of the equation.

Two additional estimating techniques are employed. An error components model is used to account for cross-section and time series differences in the error term. A ridge regression is also performed in an effort to reduce estimated coefficient inflation due to collinearity.

The choice of the multi-product function is validated by testing a single product specification. The null hypothesis is that all a_i's are equal and that all a_{ij}'s are equal for every i and j. The null is not accepted since F=17.4645.

Parameters are estimated for four different statistical procedures: OLS, error components, RR(3), and orthogenal and ridge regression (Tables 1 and 2.) Estimates for fixed cost, a_0, corresponding to bottled beer range from $549.09 thousand to $3,302.87 thousand. Introduction of draught beer is estimated to increase fixed costs by $192.06 thousand, probably brought about by increases in inventory management and the requirement that drought beer be refrigerated. The addition of canned beer increases fixed cost because of the necessity for expensive canning equipment. Estimates of the additional to fixed cost from canning range from $4,807.95 thousand to $5,630.33 thousand.

Marginal costs are highest for canned beer with the intercept of the marginal cost curve estimated to be $109.251 per hectoliter (from ridge regression), but falling throughout the relevant output range. This indicates product specific economies of scale for canned beer. Similar results are found for draught beer although to a lesser degree where marginal costs fall from a high of $55.45 per hectoliter.

The estimates for bottled beer differ from the canned and draught estimations. Bottled beer estimates indicate a U-shaped average incremental cost curve and rising marginal costs. Both a_1 and a_{11} are positive but $F(y_1)$ is larger for some output levels than is

$$(1/2)a_{11}y_1^2 \qquad (10)$$

indicating the U-shaped average curve. Canadian brewing plants could, thus, expand production of both draught and canned beer and lower their unit production costs for those plant which already produce canned and draught beer.

The ridge regression estimates indicate that any cost complementarities or anticomplementarities are insignificant and there are ray economies of scale. While cost complementarities are a sufficient condition for economies of scope, they are not a necessary condition. Large joint fixed costs can generate economies of scope even in the presence of cost anticomplementarities (Gorman, 1985.) This is the case in the brewing industry, with significant shared fixed costs for all three products giving rise to economies of scope. Unfortunately it is not possible to explicitly test for economies of scope in this case because of the producible sets of outputs. The empirical evidence reveals that most Canadian brewing plants are too small to exhaust benefits from economies of scale, but no argument can be made against the joint production of bottled, draught and canned beer.

The estimates of ray returns to scale (Table 3) indicate that firms can decrease their unit costs by either expanding existing plants or replacement of smaller plants with larger ones. An increase in canned beer production would tend to lower unit costs. Ray economies of scale are not fully exploited and small plants have ray scale elasticities as large as three. The largest plants in the sample seem to be of optimal scale, given the Canadian blend of products. Total Canadian demand could support 9.23 MES plants. While the MES plants estimated in this study are smaller than those in the US there is reason to believe that optimal scale may differ across countries (see Scherer (1975), Fuss and Gupta (1981) and Smith and Sims (1985).)

The cost of regulation can be approximated by the difference between the actual costs for the 25 plants in the sample to produce their output ($604,515,000 CA) and the estimated costs of production with optimal scale plants. Since 9.3 optimal scale plants could have produced the same output at an estimated cost of $567,300,000 CA, the cost due to regulation is approximately $37,215,000 CA or 6.5% above the optimal plant cost.

VI Implications

Canada's federal government prohibits the interprovincial trade of beer for most provinces. Canada's beer market is about ten times smaller than the U.S. market. Since Canadian national brewers are required to operate at least one plant in most of the provinces, the number of plants are more than half of the number operating in the U.S.. This is not an extreme situation. For example, there are more than one thousand breweries in the Federal Republic of Germany.

The brewing process exhibits significant economies of scale. Most recent estimates indicate that the MES plant for the U.S. is of a 4.5 million barrel annual capacity. The chairman of the board of one of the three largest brewing firms in the United States suggested that a MES plant in the U.S. should have a capacity of between 5 and 10 million barrels per year, and that a single firm providing beer for the entire U.S. market would optimally operate about 20 plants. He further indicated that transportation costs are so minimal that it is better to operate one MES plant in, for example, South Carolina, rather than operating two smaller plants closer to markets (for example in New England and Florida.)

Such estimates are not, however, appropriate for evaluation of scale efficiency in Canada or in Germany (Elzinga (1982), Scherer et al (1975), and Tremblay (1987.)

The product mix is different in each of the countries. U.S. plants primarily produce canned beer. German brewers produce mostly draught and bottled beer. Canadian brewers produce mostly bottled beer. Bottled, canned and draught beer are three different products, each with different production costs. It is not surprising that different economies of scale are associated with each of these products.

This study shows that a plant with a capacity of a little over two million barrels per year is the smallest plant that exhausts economies of scale with the Canadian mix of beer products. This MES estimate is larger than the estimate for Canadian brewing by Fuss and Gupta (1981) and about the same as the Canadian brewing study of Smith and Sims (1985.) Depreciation costs and the fact that some plants may not be able to minimize costs all of the time would suggest that total production costs are an overestimate of true costs. This implies that the smallest efficient plant would not be smaller than the MES estimated in this study.

The particular mix of beer products produced in Canada allows for MES size which is significantly smaller than that in the United States, where canned beer is produced in much larger quantities. The Canadian brewing industry operates far more plants than optimal due to Canadian regulations. With the present mix of products, 10 plants could supply the needed quantity of beer at less expense that the current configuration. If Canadians were to consume a mix similar to that in the U.S., then two or three plants would be sufficient to supply the Canadian Beer market. The social cost of scale inefficiency is estimated to be between $37 million CA and $19 million CA (at 1982 prices) and that cost is probably an underestimate of the true costs.

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Table 1

Cost Function Parameter Estimates: Pooled Observations for 25 Canadian Beer Plants for 1978 - 1982

Variable	Coefficient	Estimating Method		
		OLS	Error Components	Orthoreg
	a_0	549.098 (0.787)	1500.850 (1.009)	800.283 (1.300)
Bottled Beer (Y) output (hls.)	a_1	25.962 (8.007)	29.320 (7.792)	22.946 (7.710)
Draught Beer (Y_1) output (hls.)	a_2	54.882 (4.145)	29.793 (1.409)	52.819 (4.250)
Canned Beer (Y_2) Output (hls.)	a_3	293.515 (6.180)	457.029 (6.358)	293.631 (6.590)
Y_1^2	a_{11}	-0.004 (-1.220)	-0.013 (-3.0659)	-0.002 (-0.860)
Y_2^2	a_{22}	-0.338 (-2.007)	-0.428 (-2.825)	-0.334 (-2.120)
Y_3^2	a_{33}	-4.352 (-5.086)	-4.330 (-5.498)	-4.018 (-5.020)
Y_1Y_2	a_{12}	0.007 (0.044)	0.050 (2.877)	0.008 (0.600)
Y_1Y_3	a_{13}	0.028 (0.068)	-0.015 (-0.338)	0.021 (0.570)
Y_2Y_3	a_{23}	0.675 (2.937)	-0.278 (-0.910)	0.524 (1.990)

Adjusted R^2 0.982
Degrees of Freedom 115
t-statistics in parentheses

Table 2

Cost Function Parameter Estimates: Pooled Observations for 25 Canadian Beer Plants for 1978 - 1982
The Ridge Estimates

Variable	Coefficient	Ridge 1	Ridge 2	Ridge 3
		Estimating		Method
	a_0	2654.330	3180.660	3302.372
Intercept Dummy for draught beer (Y_2)	a_{02}			192.060
Intercept dummy for canned beer (Y_3)	a_{03}	4807.950		5630.330
Bottled Beer (Y_1) output (hls.)	a_1	29.320	25.962	22.946
Draught beer (Y_2) output (hls.)	a_2	55.463	55.156	47.338
Canned beer (Y_3) output (hls.)	a_3	109.251	178.956	78.675
Y_1^2	a_{11}	0.005	.006	.006
Y_2^2	a_{22}	-0.216	-0.205	-0.153
Y_3^2	a_{33}	-0.948	-1.396	-0.404
$(Y_1)(Y_2)$	a_{12}	0.001	0.002	0.002
$(Y_1)(Y_3)$	a_{13}	0.009	0.005	0.011
$(Y_2)(Y_3)$	a_{23}	-0.039	-0.004	-0.137
	Ridge k	0.020	0.030	0.045

Table 3

Ray Returns to Scale for the Quadratic Cost Function

Province	Average 1978-1982	Maximum Shipped Output		
Newfoundland				
Plant #1	3.3336	192	0	0
Plant #2	2.7380	234	0	0
Saskatchewan				
Plant #1	3.3858	168	8	0
Plant #2	3.4982	136	20	0
Plant #3	2.9902	203	8.4	0
Plant #4	3.5406	202	0	0
Alberta				
Plant #1	2.3712	335	25	0
Plant #2	2.0962	475	42	0
Plant #3	2.3276	398	0.1	0
Plant #4	1.6984	550	47.3	0
Manitoba				
Plant #1	2.3790	291	17.5	0
Plant #2	2.0326	333	38.1	0
Plant #3	2.5576	222	12.1	0
New Brunswick				
Plant #1	2.4360	261	17.2	0
Nova Scotia				
Plant #1	1.7502	421	53.1	0
British Columbia				
Plant #1	1.8866	564	168.5	0
Plant #2	1.6296	871	251.1	0
Plant #3	1.7112	575	119.2	36
Ontario				
Plant #1	1.2936	1306	239	0
Plant #2	1.0686	2818	342.2	47.
Plant #3	0.9994	2016	173	30
Plant #4	1.1774	1557	19.8	0
Quebec				
Plant #1	1.0942	1761	26.5	117.
Plant #2	0.9914	1938	80	0
Plant #3	1.0148	2609	141.2	143.