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ESTIMATING ECONOMIES OF SCALE IN ALASKAN INDUSTRIES

by

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This paper is an exercise in which simple (perhaps even simple-minded) comparative statics price theory and limited empirical data are used to estimate economies of scale in several Alaskan industries, with a view toward trying to estimate the effect of the structure of Alaskan industries on prices. This is important because one of the reasons given historically for the rate of inflation being lower in Alaska than in the United States as a whole is that firms in Alaska (particularly Anchorage) are characterized by economies of scale in size of firm and agglomeration economies. These economies, in the context of competition, tend to slow the rate of increase in consumer prices in Alaska. This paper first discusses a simple theoretical and empirical approach to determining whether economies of scale exist in the Anchorage support sector, discusses some modifications of the approach and some possible implications, and identifies further data needs.

The Model

Consider a simple model of a sector of the Alaskan economy characterized by "workable" competition in its product and factor markets. In other words, the prices at which the firms in this sector can sell their output and the prices which they must pay for their factors of production cannot be influenced by their own actions. Alternatively, they feel constrained in pricing of output by the real or imagined threat of entry and exit of potential competitors, and their input markets are open to entry through migration of labor, the expansion of the labor force, and the migration of capital.

The production function of this sector, f( ), is assumed to be homogenous of degree h. That is, for inputs "labor" and "capital,"

(1) $$f(t \cdot \ell, t \cdot k) = t^h \cdot X$$

where X is the level of output, and t is any constant greater than zero.

In actuality, there is nothing which guarantees that the production functions of Alaskan firms are homogenous. However, one can plausibly argue that the production function of any sector of the economy is homogenous even though those of individual firms are not. For example, one could achieve constant returns to scale by simply replicating existing firms.

For this class of production functions, Euler's Theorem states the familiar result that:

(2) $$\ell \cdot f_\ell + k \cdot f_k = h \cdot f(\ell, k), \quad f_\ell = \frac{\partial f}{\partial \ell} \text{ and } f_k = \frac{\partial f}{\partial k}$$

or, multiplying through by the price of output P and substituting X for f( ), we get:

(3) $$\ell \cdot f_\ell \cdot P + k \cdot f_k \cdot P = h \cdot P \cdot X$$

Recognizing that the value of marginal product of labor and capital are, respectively, $f_\ell \cdot P$ and $f_k \cdot P$, and that in competitive factor markets, each factor is paid its value of marginal product, then:

(4) $$\ell \cdot W + k \cdot r = h \cdot R$$

where W = wage rate in the sector

r = rate of return on capital sector

R = gross revenues for the sector

Now, in this context, if h>1, the sector is subject to increasing returns to scale; if h=1, constant returns to scale; and if h<1, decreasing returns to scale. The interesting question is whether h>1, since that would indicate that the potential returns to the factors of production are large enough to justify additional expansion in the scale of activity.

In order to do the empirical work for this paper, we need one other condition which comes out of the conditions for profit maximization in the long run, namely the definition of marginal cost. Let a firm in our arbitrary sector maximize a profit function

(5) $$\text{Max } \P_i = P \cdot X_i - W \cdot \ell_i - rk_i$$

The first order conditions for profit maximization in the long run imply

(6) $$\frac{\partial \P_i}{\partial \ell_i} = P \cdot X_i \cdot \ell - W = 0$$

(7) $$\frac{\partial \P_i}{\partial K_i} = P \cdot X_i \cdot k - r = 0$$

Rearranging (6) and (7), and dividing (6) by (7):

(8) $$\frac{P \cdot X_i \cdot \ell}{P \cdot X_i \cdot k} = \frac{W}{r}$$

or:

(9) $$\frac{W}{P \cdot X_i \cdot \ell} = \frac{r}{P \cdot X_i \cdot \ell}$$

Minimum cost conditions are somewhat less restrictive, but imply a similar relationship:

(10) $$\text{Min } C_i = W\cdot \ell + r\cdot k + \lambda\cdot(\bar{X}_i - X_i(\ell,k))$$

(11) $$\frac{\partial C_i}{\partial \ell} = W - \lambda\cdot \frac{\partial X_i}{\partial \ell} = 0$$

(12) $$\frac{\partial C_i}{\partial k} = r - \lambda\cdot \frac{\partial X_i}{\partial k} = 0$$

but for small changes in output $\bar{X}_i$,

(13) $$\frac{dC_i}{d\bar{X}_i} = \lambda,$$ which is marginal cost, and for (11) and (12),

(14) $$\frac{r}{MP_{ki}} = \frac{W}{MP_{\ell i}} = \lambda_i$$

Dividing both sides of equality by the price of output, cost minimization implies:

(15) $$\frac{r^*}{VMP_{ki}} = \frac{W^*}{VMP_{\ell i}} = \frac{MC_i}{P}$$

The relationship in (15) can be used with Euler's Theorem to estimate the degree of homogeneity of the sector production functions as long as each firm has the same value of marginal product, for several alternative pre-tax rates of return on capital.

First, suppose that increases in the value of real output during a given time period can be attributed to the sector's expanding along its long-run expansion path with no change in the ratio of labor to other factors of production. This assumption will later be relaxed. In this case, conditions specified in equation (1) hold and for a given change in the real value of total output,

$$(16) \qquad t^h = \frac{P_o \cdot f(t \cdot \ell_o, t \cdot k_o)}{P_o \cdot f(\ell_o, k_o)} = B = \frac{P_1 \cdot f(\ell_1, k_1)/v}{P_o \cdot f(\ell_o, k_o)} \quad \text{years } 1,0,$$

where P_o is the initial price level of output for the sector, and t is the proportion by which both labor and capital have increased (from (15), W/r does not change). Then, an estimate of h is obtained by

$$(17) \qquad h = \frac{\ell n(B)}{\ell n(t)}$$

In practice, the real value of output might have changed for this sector relative to all other prices. Therefore, B includes a deflator $v(^{P_1}/P_o)$, which estimates the change in the price of this sector's output compared to all other sectors, when empirical results are generated in the next section.

Unfortunately, it is not necessarily true that the economy would follow the least cost expansion path at all times, or that relative real prices (or proportions) of capital and labor would not change over time. It is possible in principle to estimate the degree of economies of scale in any time period for which one also has an estimate of the capital/labor ratio and an estimate of the marginal return on capital. In this case,

$$(18) \qquad h = \frac{W \cdot \ell + r^* \cdot S^* \cdot \ell}{R}$$

where r* is the competitive pre-tax rate of return
S* is an estimate of the capital/labor ratio

If one has some knowledge about how the wage and labor bills have changed compared to output, one can also get a rough idea of the adjustment to the economies of scale measured by (17).

The Data

The first set of estimates reported in this paper is based on gross receipts data for the Anchorage Census Division (combined city and borough) published by the Alaska Department of Revenue for the period 1967 to 1973. This period was characterized by fairly rapid development, yet not so rapid serious labor shortages developed or that real wage rates changed abruptly. In addition, this was a period during which consumer prices changed less rapidly than the United States, indicating possible economies of scale. Table 1 reports the annual average rate of change in average annual wages for the major support sector industries during this period:

Table 1

Average Annual Constant Dollar Wage,
Support Sector, Anchorage
1967-1973

(1967 Dollars)

	1967	1968	1969	1970	1971	1972	1973	Average Annual Rate of Change
Trans.-Comm.-Pub. Utilities	$10,902	$10,945	$11,331	$11,937	$11,198	$11,982	$11,800	1.3%
Wholesale Trade	10,942	11,089	11,407	11,676	11,439	11,791	11,708	1.1%
Retail Trade	7,377	7,325	7,356	7,248	7,242	7,416	7,195	-0.4%
Fin.-Ins.-Real Estate	8,167	8,362	8,583	8,721	9,113	9,365	9,440	2.4%
Services	6,620	6,652	6,836	7,204	7,324	7,773	7,713	2.6%

Table 2 reports the gross receipts data for the Anchorage support sector for 1967 and 1973, both evaluated at 1967 consumer prices. Also reported are the gross product deflators estimated for these two years, which enable us to check on the relative real price increases in each sector, as opposed to the general price level increases measured by the Consumer Price Index. Finally, total Anchorage employment is reported as a basis for estimating the expansion of scale of each sector.

Table 2

Gross Receipts, Gross Product Deflators, and Average Monthly Employment, Anchorage, 1967 and 1973

(Receipts in 10^3 Dollars)

	Gross Receipts (1967 Consumer Prices)		Gross Product Deflator (1967=100.0)		Employment	
	1967	1973	1967	1973	1967	1973
Trans.-Comm.-P.U.	$45,118.9	$61,095.5	100.0	112.2	2,771	4,625
Wholesale Trade	84,689.0	187,810.7	100.0	114.9	1,575	2,475
Retail Trade	170,611.1	411,854.7	100.0	115.4	4,686	8,188
Fin.-Ins.-R.Estate	37,083.7	106,510.3	100.0	100.0	1,363	2,803
Services	39,562.2	144,423.9	100.0	134.0	4,332	8,319

Gross receipts data reported here are collected by the Department of Revenue in connection with the Business License Tax and Gross Receipts Tax. In the period for which these data are reported, the businesses reported their receipts according to two-digit SIC classification, which was further aggregated into the industry groups shown here. This was done to minimize problems created by firms switching their reported industry in which they do business. The banking sector (SIC 60), within Finance-Insurance-Real Estate, pays a net receipts tax, and the data show unexplained variability in that sector which tend to suggest net receipts are sometimes reported. "Professional" receipts appear to be best categorized as services receipts, and these were added to services for 1967 (this was not necessary in 1973).

The gross product deflators used in the study were estimated for Alaskan industries by regressing U.S. average employee compensation by industry to U.S. implicit price deflators by industry for the years 1961-1972. For each industry, Alaskan regional wages and salaries were multiplied by the ratio of U.S. employee compensation by industry to U.S. wages and salaries. This estimate of Alaskan regional employee compensation was divided by employment to get annual compensation per employee, which was then entered into the U.S. implicit price deflator predictive equation.

Employment data came from the Alaska Department of Labor, which classifies its sectors according to SIC criteria.

Results

Table 3 shows the initial results obtained by estimating equation (17), which assumes no change in the capital/labor ratio in the Anchorage support sector industries. The degree of "economies of scale" suggested by the last column can be interpreted as follows: If both labor and capital were doubled in the Anchorage economy during this period, real output would expand by 2^h times; e.g., $2^{1.457} \doteq 2.745$ times in Wholesale Trade. Also, the wholesale trade markup on items sold through Anchorage wholesalers should have fallen.

Table 3

Results of Economies of First-Round Scale Estimates,
Anchorage Support Sector,
1967-1973

	t	v	B	h
Trans.-Comm.-P.U.	1.669	1.122	1.207	.366
Wholesale Trade	1.571	1.149	1.930	1.457
Retail Trade	1.747	1.154	2.092	1.323
Fin.-Ins.-R. Estate	2.056	1.000	2.872	1.464
Services	1.920	1.340	2.724	1.536

One puzzling result is that for transportation, communications, and public utilities. There is always a possibility of faulty reporting of gross receipts in that sector, but examination of the raw data reveals no glaring data differences. However, it may be that some of the employment gains in this sector in Anchorage are not reflected in Anchorage sales increases. An obvious candidate is SIC42, Trucking and Warehousing. The data for 1973 and 1974 show that Anchorage sales in this sector went up 17 times in real terms between 1973 and 1974, while employment increased only 47.6 percent. This suggests that much of Anchorage activity in this sector simply went unreported in Anchorage gross receipts data. Allowing for no gains in output per worker in this subsector and adjusting the 1973 and 1967 sales data, B = 1.185. If, as seems more likely, real output per worker had as much as doubled in industry 42 between 1967 and 1973, B = 1.724 and h would then be 1.063. However, this whole exercise may have demonstrated that for transportation, anyway, Anchorage was not the appropriate unit of analysis.

It would be interesting to do some alternative estimates of economies of scale, permitting the capital/labor ratio and estimated returns-to-capital to vary. This in general requires an estimate of capital stock, which is not available by industry for Anchorage or Alaska at this time. In principle, it is possible to estimate the capital stock for business sectors in taxing jurisdictions such as Anchorage. In practice, it would mean very involved and meticulous calculations on the raw assessment data or book value data including allocation of multiple-use office buildings to the actual occupiers. There would still remain the problems of estimating the rate of return on that capital.

It would also be worthwhile to compare economies of scale as measured in this section with equivalent national figures. Estimates done for the years 1965 to 1973 for the U.S. retail "industry" and wholesale "industry" as a whole show h equal to 0.79 and 1.567. What meaning this gross a figure may have is extremely unclear.

It is also interesting to attempt a calculation of the amount of the observed increase in output attributable to economies of scale and the amount attributable to changes in factor proportions to see what data are necessary. If we can assume that $r \cdot k$, the total return to capital, changed in a known way during the period 1967-1973, then there is a possibility of estimating an adjusted economies of scale parameter. Table 4 shows the change in real wage rate, the increase in the value of output per employee, and some adjustments to the economies of scale measure developed in the previous table.

Table 4

Adjusting h for Changes in the Capital/Labor Ratio

	% Change 1973 to 1967 real wage	Output/Labor Ratio 1967	1973	% Change	y	Adjusted h for Capital Bill: Constant	Up 10%
Trans.-Comm.-P.U.	+ 8.2	16.2825	11.7735	- 27.7	NA	NA	NA
Wholesale Trade	+ 7.0	53.7708	66.0427	+ 22.8	17.5	1.202	1.056
Retail Trade	- 2.5	36.4087	43.5873	+ 19.7	13.1	1.150	1.017
Fin.-Ins.-R. Estate	+ 15.6	27.2074	37.9987	+ 39.7	22.1	1.141	.994
Services	+ 16.5	9.1325	12.9558	+ 41.9	32.9	1.031	.8771

Note in Table 4 that even though labor supply has increased and the real wage has risen, output per worker generally has risen by more than the wage rate, implying labor's share has fallen, and that capital's share may have increased. If r, the rate of return on capital were constant, for example, then this implies that k/ℓ would have risen during the period. If r had risen by more than w, then k/ℓ would have fallen, and so on. We originally attributed changes in output solely to economies of scale. However, if the capital/labor ratio is changing, this is incorrect. The h originally estimated was an elasticity of output as both inputs are changed by the same proportion. The last two columns show h as adjusted for specified changes in the capital bill as the economy expands.

If the rise in w, the real wage, completely captures the increase in the number of efficiency units of labor per worker, then even without economies of scale, the wage bill would rise by the number of old workers times their increase in efficiency, plus the new workers times their efficiency. The amount of the total change in output taken up by a change in the wage bill alone, y, is estimated in the table. The remainder of the output change is allocated to the capital bill and the economies of scale. If the capital bill was unchanged and h was measured as before, then $(1-y)\cdot h$ is the proportion of measured h due to the increase in economies of scale. If the capital bill changes make up 10 percent of the observed changes in output, equal to $h\cdot f(k,\ell)$, then $(1-y-.10)h$ is due to economies of scale. Obviously, real data on the capital stock are necessary for estimates with real content, although these calculations demonstrate how the adjustment might be done.

Can we judge what the future effect on prices would be of changes in the level of economies of scale? The following calculations illustrate the logical links. We note that the Alaska Relative Price Index, which is used to measure the rate at which Alaska prices rise in lower 48 terms, went up 23.2 percent between 1967 and 1973, while the U.S. CPI went up 33.1 percent. The relative Alaska cost of living fell to 31.9 percent above the United States (from 42.5 percent in 1967). The decrease in the gap was 24.9 percent over the period. Without knowing the average markups of the consumer-purchased commodity and service bundle at each level of the economy, it is impossible to directly estimate the effect of economies of scale on consumer prices. It does appear from Table 3, however, that the "average" h (uncorrected) was about 1.45. Then doubling the scale of inputs while doubling population would have the following effect:

Let X/N be output per capita, P be the price of output in base period dollars, which is held constant. Then

$$(19) \qquad d\left(\frac{XP}{N}\right) / \frac{XP}{N} = \frac{PX}{N} \cdot \frac{N}{P\cdot X} - \frac{dN\cdot PX}{N^2} \cdot \frac{N}{X} = \frac{P\cdot dX}{P\cdot X} - \frac{dN}{N}$$

but since dX in this case would be due to proportional increase of both factors of production,

$$(20) \qquad d\left(\frac{XP}{N}\right) \Big/ \frac{XP}{N} = \frac{P_o(t^h-1)X_o}{P_oX_o} - \frac{(t-1)N_o}{N_o}, \quad t = \text{proportionality constant}$$

Since t = 2 (doubling inputs) and h = 1.45 (observed in Table 3), the potential expansion of output per capita is .732 or 73.2 percent. During the period 1967 to 1973, the base period value of output in the support sector (excluding Trans.-Comm.-P.U.) expanded 121 percent, while population expanded 39 percent for an increase of 82 percent in the output per capita. This resulted in a decrease of about 24.9 percent of the existing difference in the cost of living between Anchorage and the rest of the United States existing in 1967. If the relationships prevalent in the period 1967-73 held, then each doubling of the economy (accompanied by a doubling of the population) would reduce the Alaska/U.S. gap by about

$$\text{Percent reduction} = 73.2 \times \frac{24.9}{82.0} = 22.2 \text{ percent}$$

provided no short-term supply bottlenecks developed. Obviously not all of the price "reductions" from 1967-73 can be attributed to economies of scale. Transportation, climate, and some erosion of monopoly power undoubtedly played a role in the historic period price reductions. Furthermore, it is likely that not all of the gains in output occurred because of increases in scale of operations, but rather because of technological improvements, or because of increased capital relative to labor. Thus, the projected percentage reduction is probably the <u>largest</u> reduction in prices that could occur due to a doubling in size of the Anchorage economy if costs of transportation, etc., were held constant. The actual value is likely to be considerably smaller.

Conclusion

This paper shows about how far the existing data can take us in estimating economies of scale in this theoretical framework. Obviously, there are a whole series of heroic (or foolhardy) leaps necessary on both the theoretical and econometric side necessary to deduce whether and to what degree economies of scale have influenced Anchorage prices. Additional leaps are necessary to discuss whether (1) economies would continue to exist and (2) whether other areas in Alaska could expect similar effects on prices. Yet, prices are crucial since they determine real wages and incomes, influencing real economic growth, purchasing power of government dollars, and migration to Alaska.

The paper demonstrates that in order to estimate economies of scale under all but the crudest assumptions, it is necessary to have data on both the capital stock in Alaska and the rate of return on that stock. It may be possible to generate such estimates, and we are currently looking into the possibility of using book value of corporate capital and assessed valuations to derive such estimates (this is completely aside of issues raised by the existence of other cooperating factors of production). In order to go further and demonstrate the expected future effect on prices, a fairly detailed study must be conducted on why apparent economies of scale existed in the past to determine whether they could be expected to continue. Second, the links between expanded production, unit costs at the various levels in the distribution chain, and changes in unit prices need further investigation.

We have shown that scale economies alone probably could not contribute more than about a one-quarter decrease in the current gap between Anchorage and Lower 48 costs of living. Thus, it is important to examine the specific components of the cost of living which can be affected by public policy in order to determine where other possibilities for reduction in cost lie. One very good public policy candidate is the cost of land, which represents a substantial portion of the price of housing, a significant source of the Anchorage/Lower 48 cost differential. When one looks at the state as a whole, utility prices and transportation costs become more important. In addition, scale economies loom as a much larger consideration for the remainder of the state. As we all know, economies of scale are limited by the extent of the market, but in Alaska it may be that innovative public policy in transportation, for example, might achieve some of those economies in the rural areas by effectively expanding the size of markets of some of the existing trade centers.