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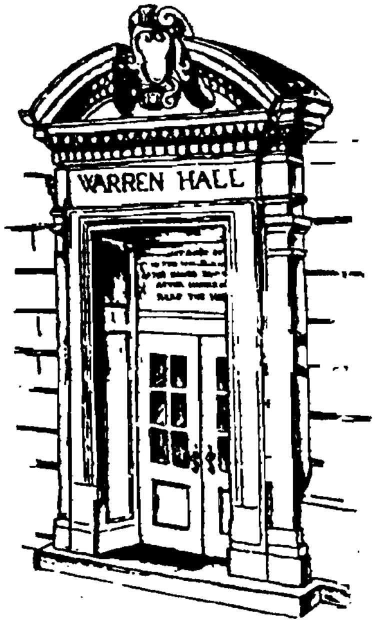

Staff Paper

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AGE AND FARMER PRODUCTIVITY

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Abstract

Farmer productivity by age was estimated, allowing for differences because of efficiency and returns to scale. Using Census of Agriculture data, estimates vary by state, but returns to scale average 1.07. Efficiency increases average 4.5 percent every ten years of age, to the age interval 35 to 44, and then decreases at that same rate.

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AGE AND FARMER PRODUCTIVITY

Introduction

It is believed that as a farmer ages and gains experience he or she becomes more productive with improved managerial ability. Productivity may fall later in life. An early study by Loomis, reinforced by Long, found a cyclical relationship between the age of farmers and size of the farm, use of some inputs, and output. More recently, Tauer used 1978 Agricultural Census data and concluded that farmers do display first an increase and then a decrease in productivity, with farmers between the ages of 35 and 44 being the most productive. The average age of U.S. farmers in 1978 was 50.3 years, an age cohort that was 6 percent less productive than those farmers aged 35 through 44. The average age of U.S. farmers is now 52.0 years (1987 Census).

This paper estimates farmer productivity by age but uses a different approach than estimating separate production functions for different age groups, as used by Tauer. The procedure used assumes that the agricultural technology within a state is consistent across age groups within that state, but that farmers of various ages may display different efficiencies in utilizing that technology, and may also use different levels of inputs in a technology that may not exhibit constant returns to scale.

Theory

The production of two different age groups in a state can be represented by the following relationships:

$y_0 = A(\theta_0)\, f_s(x_0)$

$y_1 = A(\theta_1)\, f_s(x_1)$

where $f_s(x_i)$ is the production function for a specific state, s, and x_i is the input quantity used by age group 0 or 1, and y_i is the resultant output; $A(\theta_i)$ is the efficiency factor for age group i.

This specification assumes that the underlying production technology is the same across all age groups in a specific state, but that these age groups may use different quantities of inputs and may display varying levels of efficiencies. This seems more appropriate than assuming that technology differs by age, and acknowledges that agricultural production technology may differ significantly across contrasting regions.

The relative efficiency of group 1 relative to group 0 is:

$$\frac{A(\theta_1)}{A(\theta_0)} = \frac{y_1\, f_s(x_0)}{y_0\, f_s(x_1)} .$$

Taking the natural log:

(1) $T(1,0) = \ln A(\theta_1) - \ln A(\theta_0) = \ln y_1 - \ln y_0 + \ln f_s(x_0) - \ln f_s(x_1).$

If $f_s(x)$ can be approximated by a translog form, then for a cost-minimizing firm the Tornquist input index can be substituted for $f_s(x)$, where the index is:

$$\varepsilon \sum_j \left(\frac{w_j\, x_j}{c} \right) \ln(x_j) .$$

ε is the scale elasticity, w_j is input price j, x_j is the quantity of input j, and c is total costs, $\sum_j w_j\, x_j$ (Diewert).

Substituting the Tornquist input index into (1) produces:

(2) $$T(1,0) = \ln y_1 - \ln y_0 - \varepsilon(1,0) \sum_j 1/2 \; [V_{j1} + V_{j0}] \; [\ln x_{j1} - \ln x_{j0}],$$

where V_{ji} is the input cost share for factor j, firm i.

Given empirical data for y, x and w, the unknowns in equation (2) are T and ε. Typically, ε is assumed to be equal to one, representing constant returns to scale, and T is then calculated. However, if data for three or more age cohorts are available, and assuming that T and ε are constant, then T and ε can be estimated from

$$[\ln y_1 - \ln y_0] = T + \varepsilon \left[\sum_j 1/2 \; (V_{j1} + V_{j0}) \; (\ln x_{j1} - \ln x_{j0}) \right] + \mu_i$$

where T is the intercept and ε is the slope of a linear regression with error term μ_i (Chambers).

If farmers of various age groups in a state use approximately the same quantity of inputs, it is reasonable to assume that the scale of that technology is constant over that range of inputs. Much less tenable is an assumption that the relative efficiencies between any adjacent age groups change monotomically. In fact, the expectation is for first an increase in relative efficiency as age increases, some peak in efficiency during mid age, and then a decrease in efficiency in the older age groups.

The data available by state have five usable age cohorts. Since the dependent and independent variables are first differences, four observations are available to estimate each state model. This sparse data set provides limited model specification while retaining any statistical degree of freedom.

One specification is to assume a symmetric efficiency model with a peak in efficiency at the middle age cohort, with constant increases in efficiency between the age groups up to that peak and then the same constant but decrease in efficiency between age groups after the peak age. That model can be estimated using an intercept coefficient for efficiency and one slope coefficient for scale by forward-differencing between age groups to the middle age and then backward-differencing past the middle age. The data differencing becomes D(2,1), D(3,2), D(3,4), and D(4,5), where 1, ..., 5 are the five age groups. Alternatively, peak efficiency can be shifted one age to the left or right by an earlier or later shift from forward to backward differencing. With four observations and two coefficients to estimate per state, this model only has two degrees of freedom.

An alternative specification is to assume a nonsymmetric efficiency model, again with a peak in efficiency at the middle age cohort, with constant increases in efficiency between age groups up to that peak, but then a different constant decrease in efficiency between age groups after the peak year. This model an be estimated by using an intercept shifter for the last two differences. If the intercept dummy is a negative value, the decrease in efficiency as farmers age past the middle age cohort is not as great as their increase in efficiency up to the middle age cohort. A negative dummy intercept with an absolute value greater than the intercept implies productivity continues to increase beyond mid age. A positive intercept dummy implies efficiency decreases faster than the early age increases. Again, peak efficiency can be shifted one age to the left or right. With a dummy intercept shifter, this model only has one degree of freedom.

Both models will be estimated for each state. However, with sparse data and low degrees of freedom, each observation can have a large influence on the parameter estimates, and one aberrant observation would produce a coefficient very different from the population parameter. The first model is also nested in the second model since rejection of the statistical significance of a dummy intercept shifter implies acceptance of symmetry in efficiency changes to and beyond the middle age cohort.

Data

The 1987 Census of Agriculture includes data from operators who indicated that their major occupation is farming, summarized by state into six age intervals: under 25 years of age, 25 to 34 years, 35 to 44 years, 45 to 54 years, 55 to 64 years, and over 65 years of age. These data for 44 states were used to estimate the productivity between age groups in each state. (Alaska, Connecticut, Hawaii, Nevada, New Hampshire, and Rhode Island were omitted because of the unavailability of data for some age groups because of non-disclosure rules.)

The output variable is the sum of the market value of agricultural products sold, plus income from machine work, custom work, and other agricultural services, plus direct government payments. This output variable reflects sales during the calendar year of 1987 rather than an accrual measure of production. Since data are an average over all farmers in an age group, inventory changes should average out over all farmers. This would not be the case if a majority of farmers are increasing or liquidating their inventories. This appears to be occurring in the group of farmers over age 65. Their sales, and resultant productivity, are much higher than any other age group, and I suspect that they are slowly liquidating livestock herds as a means to gradually exit from farming and to generate retirement income. That age group was excluded from the analysis to prevent any biased estimate of productivity.

The Census data include the average value of land and building used (owned and rented) per farm. No information is available on vintage or quality of these assets to convert to a differentiated flow of service by age, so the values were converted into a flow by multiplying by 10 percent, reflecting an average rent value in agriculture. Likewise, only the value of machinery and equipment were available, and it was converted to a flow by multiplying by 20 percent, reflecting a depreciation rate of 15 percent and an interest rate of 5 percent. If young farm operators have equipment newer than average, and older farmers have equipment older than average, then young operators' equipment services are going to be small relative to the value of their stock, while older farmers' equipment services will be larger. Some young farmers may also be borrowing significant amounts of machinery services from older farmers, either gratis or by trading labor.

Grouped together as livestock expenses were livestock and poultry purchases, plus feed for livestock and poultry, while crop expenses were defined as the sum of fertilizer, chemicals including lime, and seed, bulb, plant, and tree purchases. All energy and petroleum expenses were treated as an energy input. Grouped together as hired labor and custom expenses were hired farm labor, contract labor, and custom work hired. The Census category of "all other production expenses" were defined as miscellaneous expenses.

Livestock breeding inventory is not converted into an input flow because of inherent problems of constructing that variable. Correctly measuring the service flow from breeding stock requires much the same information as does machinery, none of which were available by age group. With machinery, however, the value of inventory is collected which reflects variations in both machinery quantity and quality. Only livestock numbers and not values are collected, and assigning an inventory value or service flow to each livestock type assumes that livestock age and quality are homogeneous across age groups. More problematic however, is the fact that the purchased livestock expenditure variable combines breeding and feeder purchases. Using livestock inventory, but no expenses, would exclude feeder livestock purchases not inventoried at the Census date, while including both inventory and purchases would double-count some livestock. Thus, livestock purchases were used as a variable with no flow from inventory. Since all the expenses of producing breeding livestock should be included in other expense items, the input costs of raising replacement livestock is implicitly included, although some of those expense may have occurred during previous years.

No family labor data are available from the Census unless the family labor was paid a wage, in which case it would be included as labor expense. The only data on operator labor are the number of days of work off the farm, grouped by number of respondents into four categories: none, 1 to 99 days, 100 to 199 days, and 200 days or more. An average composite of hours worked on the farm was compiled by subtracting from an assumed 250 days available, a weighting of the number of respondents in each of the four groups by their respective means -- 0 days, 50 days, 150 day, and 250 days -- and then dividing by the total number of respondents. Days were converted into hours based upon an eight hour day and then total hours were multiplied by the hourly wage rate for agricultural labor in that state.

These eight inputs were aggregated using the Tornquist index. Expenditures rather than quantities were used. This should not bias results if input prices are identical across age groups in a state since the prices would cancel. Differences between age groups were computed by forward-differencing to the age cohort 35 to 44 years, and backward-differencing beyond that cohort. Tauer found the age cohort 35 to 44 to be the most productive, and for most states those farmers have the largest sales per farm.

Results

Although both model one and model two were estimated, and model two is nested in model one, only the results for model one will be reported since those results were more consistent with expectations and were much more robust across individual state equations. Coefficients from model two varied significantly across states, with extremes especially among the scale estimates.

For most states, the data fit model one quite well. Twenty of the 44 state equations have adjusted R^2 values of at least .90, and only six states had adjusted R^2 values below .50, three of those negative.

The scale coefficient is expected to be close to -1, with an absolute value greater than 1 reflecting increasing returns to scale, and an absolute value less than 1 reflecting decreasing returns to scale. Four states display scale coefficients that are numerically close to 0 or of the wrong sign - Delaware, Maryland, South Carolina, and Virginia. These are all Mid Atlantic states, and all have negative or low adjusted R^2 values.

Although not necessary, the expectation is that the age coefficient, which measures the percentage change in productivity between adjacent age cohorts, would be positive, reflecting a symmetric increase and then decrease in efficiency. Seven of the forty-four age coefficients were negative, which implies the lowest productivity occurred at mid age. All but one of these were from equations with adjusted R^2 values above .80. However, except for a few cases, the standard errors on the age coefficient were larger than the coefficient estimates, implying the coefficient estimates may be inefficient.

The standard errors on the scale coefficients were relatively lower, explaining most of the good fit of the equations as reflected by high R^2 values. Yet, a statistical test of whether the scale was significantly different than absolute 1 failed for all states except for Georgia, South Dakota, and West Virginia.

Some patterns are apparent with similar or contiguous states. South Dakota is one of two states that have both statistically significant age and scale (H_o=1) coefficients, with decreasing returns to scale of .92, and productivity increasing and then decreasing 3.7 percent between adjacent age cohorts. Although not statistically significant, Nebraska has a scale of .98 and productivity changes of 3.6 percent. North Dakota has scale of .97 and productivity change of 6.6 percent. Kansas is similar. In the corn belt, Missouri has a scale coefficient of 1.16 and a productivity change coefficient of 4.4 percent; Iowa has scale of 1.13 and productivity of 2.6 percent; and Minnesota has scale of 1.13 and productivity of 3.2 percent. Other states that have similar coefficients include Kentucky and Tennessee, New York and Pennsylvania, and Oregon and Washington. Yet Alabama, with a scale of 1.11 and efficiency of 8.0 percent, is quite different from Georgia's scale of 1.84 and productivity of -15 percent, both of which are measured as statistically significant.

From a statistical stance, one would have to conclude that productivity does not vary by age, and constant returns to scale is the norm. However, given the limited degrees of statistical freedom, a more reasonable approach might be to interpret the estimates collectively for all states without formal statistical inference. Excluding the six states with R^2 values below .50, the average scale for the remaining 38 states is 1.07 (standard deviation .28), and the average age productivity is 4.5 percent (standard deviation of 7.1). This implies productivity increases and then decreases with age, and increases with size.

Tauer earlier found that the middle-aged farmers were 30 percent more productive than the youngest and oldest groups. His approach entailed estimating separate production functions for each age groups using state observations as data. Since the middle-aged farmers in most states were the largest, they were able to capture economies of scale, as reflected in the estimates of their age production function. When a constant input basket of inputs was inserted into each age production function the middle-aged farmers were found to be the most productive not only because of productivity increases associated with age but also because they were able to capture economies of size.

In contrast, the estimates here indicate that the middle-aged farmer is 9 percent more productive than the youngest farmer because of experience (4.5 percent per age cohort and two age cohorts removed). Any further increase in productivity is due to economics of size, with most middle-aged farmers having larger operations than the youngest age cohort farmer.

Summary

Farmer productivity by age was estimated for individual states using 1987 Census of Agriculture data. The procedure used assumes farmers of individual states use the same technology but that technology may not exhibit constant returns to size, and farmers of various ages may display different efficiencies in utilizing the technology. Estimates of scale and efficiency vary by state, but on average, scale appears to be 1.07. Efficiency increases 4.5 percent for each decimal age group to the most productive age group of 35 to 44 years, and then decreases 4.5 percent for each decimal age group after that mid age interval.

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Table 1. Linear Regression to Separate Productivity into Age (Symmetry) and Scale Components.

State	Age (standard error)	Scale (standard error)	Adj. R^2
Alabama	0.0802	-1.1137	0.94
	(0.0410)	(0.1556)	
Arizona	-0.0553	-1.1649	0.58
	(0.2647)	(0.5164)	
Arkansas	0.0842	-0.8431	0.83
	(0.0631)	(0.2118)	
California	-0.0203	-1.3450	0.91
	(0.0631)	(0.2403)	
Colorado	0.0930	-0.6299	0.51
	(0.1158)	(0.3103)	
Delaware	0.1833	-0.0457	-0.49
	(0.1013)	(0.5815)	
Florida	-0.0326	-1.3553	0.82
	(0.0831)	(0.3481)	
Georgia	-0.1497*	-1.8398**	0.96
	(0.0483)	(0.2125)	
Idaho	0.1621	-0.5189	0.54
	(0.0945)	(0.2440)	
Illinois	0.0041	-1.1915	0.94
	(0.0514)	(0.1753)	
Indiana	0.0332	-1.2299	0.98
	(0.0248)	(0.1047)	
Iowa	0.0258	-1.1305	0.91
	(0.0558)	(0.2067)	
Kansas	0.0649	-0.9710	0.95
	(0.0608)	(0.1241)	

Table 1. Linear Regression to Separate Productivity into Age (Symmetry) and Scale Components (continued).

State	Age (standard error)	Scale (standard error)	Adj. R^2
Kentucky	0.0439 (0.0979)	-1.1980 (0.3687)	0.76
Louisiana	0.1445 (0.0759)	-0.6026 (0.2966)	0.51
Maine	0.0849 (0.1129)	-0.8072 (0.2331)	0.79
Maryland	0.1855 (0.1109)	-0.3401 (0.6035)	-0.29
Massachusetts	0.1202* (0.0376)	-1.2476 (0.1040)	0.98
Michigan	0.0804 (0.0331)	-0.9667 (0.0888)	0.97
Minnesota	0.0325 (0.0612)	-1.1302 (0.2584)	0.86
Mississippi	-0.1424 (0.0549)	-1.4973 (0.1852)	0.95
Missouri	0.0440 (0.0168)	-1.1589 (0.0576)	0.99
Montana	0.0261 (0.0248)	-1.1041 (0.0895)	0.98
Nebraska	0.0358 (0.0584)	-0.9863 (0.1359)	0.94
New Jersey	0.1287 (0.0656)	-0.6027 (0.1508)	0.83
New Mexico	0.1570 (0.0920)	-1.0475 (0.2225)	0.87

Table 1. Linear Regression to Separate Productivity into Age (Symmetry) and Scale Components (continued).

State	Age (standard error)	Scale (standard error)	Adj. R^2
New York	0.0654 (0.0328)	-0.9279 (0.1472)	0.93
North Carolina	0.0473 (0.0462)	-1.1791 (0.1546)	0.95
North Dakota	0.0664 (0.0683)	-0.9771 (0.2947)	0.77
Ohio	0.0434 (0.0654)	-1.1596 (0.2637)	0.86
Oklahoma	0.0750 (0.0460)	-1.0954 (0.1145)	0.97
Oregon	0.1491 (0.0790)	-0.7475 (0.3616)	0.52
Pennsylvania	0.0605 (0.0360)	-0.9937 (0.1461)	0.94
South Carolina	0.4112 (0.1834)	0.8670 (0.7645)	0.09
South Dakota	0.0370* (0.0078)	-0.9212** (0.0220)	0.99
Tennessee	0.0468 (0.2092)	-1.1335 (0.8093)	0.24
Texas	0.1100 (0.0631)	-0.7905 (0.1524)	0.90
Utah	0.0236 (0.1122)	-0.8269 (0.2334)	0.79
Vermont	-0.0299 (0.0564)	-1.2444 (0.3061)	0.84

Table 1. Linear Regression to Separate Productivity into Age (Symmetry) and Scale Components (continued).

State	Age (standard error)	Scale (standard error)	Adj. R^2
Virginia	0.1751	-0.3896	-0.44
	(0.2267)	(1.4204)	
Washington	0.1656	-0.6882	0.29
	(0.1201)	(0.4613)	
West Virginia	0.0349	-1.6807**	0.96
	(0.0447)	(0.2026)	
Wisconsin	0.0156	-1.2629	0.76
	(0.0684)	(0.3855)	
Wyoming	-0.0509	-1.3622	0.84
	(0.1253)	(0.3337)	

* Statistically different from zero at probability .10.

** Statistically different from one at probability .10.

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