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Did the Baby Boom Cause the Farm-Size Boom?

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Abstract. Growing farm size has generally been explained by technological advances that have allowed farmers to substitute capital for labor. Another possible factor in explaining recent farm size is the demographic shift: the age distribution of farmers has shifted to the right and older farmers generally operate larger farms than younger farmers. This paper uses data from the 1982, 1987, 1992, 1997, and 2002 Agricultural Censuses to examine the relative importance of the demographic shift versus technological factors in explaining overall farm size growth. Results indicate that farm sizes tend to increase with age and that, holding age constant, the typical farm-size has increased over time for all ages, presumably due to technological change. The age-distribution shift is combined with the age-specific farm-size shift, to provide a preliminary estimate of the effect of the age distribution shift and technological change on average farm size growth.

Keywords: farm structure, demographic shift, age distribution, farm size distribution

* The views expressed are those of the authors and do not necessarily correspond to the views or policies of ERS, or the U.S. Department of Agriculture.

Introduction

For many generations, farms in the United States have been steadily growing in size. Between 1935 and 1982 average farm size grew from 135 to 431 acres. In recent decades, the trend toward larger farms has continued and perhaps even accelerated, although some standard agricultural statistics, like average farm size, tend to mask this trend: by 2002, average farm size was just 441 acres. The main reason for slowdown in average farm size growth is a growing relative proportion of very small farms operated by households with primary occupations outside of farming. These farms, while large in number, produce very little output, but strongly influence average farm size. The farm size associated with the typical unit of production, however, continues to grow. The *weighted-median farm size*—the size for which half of land resides on larger farms and half on smaller farms—grew from 1620 acres in 1982 to 2190 acres in 2002. Other farm size measures show similar and in some cases much more striking increases in recent decades.

While production has been shifting to larger farms for many years, economists broadly understand this trend to be a by-product of the innovations that have brought vast economic growth and employment opportunities outside of agriculture – from the factories of a century ago to the service sectors of today. Farms have substituted capital—such as bigger and faster tractors and combines, computerized information systems, and automated harvesting equipment—for the labor that has left agriculture for other sectors of the economy. These substitutions have allowed more agricultural output to be

produced by fewer and fewer farmers, and allowed farmers to operate much larger farms (Kislev and Peterson, 1983).

In addition to technological change, in recent decades US agriculture has experienced a demographic shift. In part because of the baby boom, the age distribution of farmers has shifted to the right: farmers have become older. This shift has potentially important implications for farm structure. In a longitudinal analysis of individual farms, Gale (1994) and others have documented a strong link between farm size and operator age. Gale writes, “Young farmers and new entrants have smaller farms, grow faster, and are less likely to own farmland than older, more experienced farmers. Farmers tend to decrease farm size at advanced ages.” In recent years, these patterns have continued, although the relative frequency of both new entrants and exits have declined. Older farmers have postponed retirement, maintaining their large farms longer than before. Since older farmers tend to operate larger farms (because of capital accumulation or life-cycle related reasons) some of the overall shift toward larger farms is likely attributable to the demographic shift rather than to technological change.

In this paper we use data from the 1992, 1997, and 2002 Agricultural Censuses to examine the relative importance of the demographic shift versus technological factors in explaining the overall farm size growth. In a preliminary analysis, we find, like Gale, that farm sizes tend to increase with age. We also find that, holding age constant, the typical farm-size has increased over time for all ages, presumably due to technological change. Finally, we combine the age-distribution shift with the age-specific farm-size shift, to provide a preliminary estimate of the effect of the age distribution shift and technological change on average farm size growth.

A Simple Equilibrium Model

This section develops a simple equilibrium model that can be used to explain typical farm size as a function of technology and the age distribution of farmers.

Suppose each farm i has a profit function $\pi(L_i, A_i, t, \varepsilon_i)$, where L_i denotes land area (our farm-size measure), A_i denotes the operator's age, t denotes the set of technologies and prices at time t , and ε_i is a set of other individual factors that affect both profits and farm size. Define $f(L_i, A_i, t, \varepsilon_i)$ as the partial derivative of profits with respect to L_i , or the marginal productivity of land. Profit maximizing farmers choose L_i^* so that marginal productivity of land equals the rental rate, denoted by r .

$$(1) \quad f(L_{it}, A_{it}, t, \varepsilon_{it}) = r_t$$

Assuming $f_L < 0$, a sufficient condition for profit maximization, (1) can be implicitly solved to give

$$(2a) \quad L_{it}^* = g(A_{it}, t, r_t, \varepsilon_{it}),$$

wherein maximization implies the function $g()$ is everywhere decreasing in r .

Equilibrium farm sizes and rental rates are determined from the simultaneous solution of (2a) for all farms combined with an aggregate land constraint

$$(2b) \quad \sum_i g(A_{it}, t, r, \varepsilon_{it}) = \bar{L},$$

where \bar{L} is total land area.

Over time, the age distribution of farm operators may change as each operator ages, some exit, and new farms enter. If the equilibrium farm size described by g is increasing in A_{it} and there is a rightward shift in the age distribution, then productivity increases (from (1)) as does the average farm size. In aggregate, this drives up land rental rates in equilibrium, which reduces farm sizes of younger farms and limits growth of farms operated by older farmers. Similarly, if a new technology increases the marginal productivity of land for all farms, it will cause some farms to expand, land rental rates to rise, and some farms to exit. Thus rental rates are endogenous to t and the farm population distributions of A_{it} , and ε_{it} . Because ε_{it} includes idiosyncratic factors like farm operator skills and preferences and farm location, these factors likely average out to zero in aggregate farm size measures. Thus, in reduced form an aggregate measure of farm size is an implicit function of technological factors and the age distribution.

To decompose farm size changes into technological and demographic factors, we need to put some structure on the equilibrium defined by (2a) and (2b). This structure is developed by assuming a separable form for the function $g()$:

$$(3) \quad g(A_{it}, t, r, \varepsilon_{it}) = \frac{l(A_{it})h(t)\varepsilon_{it}}{\phi(r_t)}.$$

Substituting (3) into (2b) gives:

$$(4) \quad \phi(r_t) = \frac{h(t) \sum_j l(A_{jt}) \varepsilon_{jt}}{\bar{L}}.$$

Substituting (4) back into (3) gives:

$$(5) \quad L_{it} = \frac{\bar{L} l(A_{it}) \varepsilon_{it}}{\sum_j l(A_{jt}) \varepsilon_{jt}}.$$

In this formulation, where rent and technological effects are each multiplicatively separable from other factors, individual farm size is unaffected by exogenous change in technology. Rather, in equilibrium, technological change simply affects rents, and farm size remains unchanged, individual farm size is only a function of individual factors and the aggregate sum of individual life-cycle effects.

To allow for interactions between life-cycle and technological factors another formulation of $g()$ makes life-cycle effects a power function of technological factors:

$$(6) \quad g(A_{it}, t, r_t, \varepsilon_{it}) = \frac{l(A_{it})^{h(t)} \varepsilon_{it}}{\phi(r_t)}.$$

Solving for equilibrium L_{it} in this case gives:

$$(7) \quad L_{it} = \frac{\bar{L} l(A_{it})^{h(t)} \varepsilon_{it}}{\sum_j l(A_{jt})^{h(t)} \varepsilon_{jt}}.$$

Taking the natural log of (5) gives

$$(8) \quad \log(L_{it}) = \log(\bar{L}) + h(t)\log(l(A_{it})) - \log\left(\sum_j l(A_{jt})^{h(t)} \varepsilon_{jt}\right) + \log(\varepsilon_{it}).$$

This equation can be estimated using panel data on individual farms sizes and operator ages. With land area assumed fixed, the natural log of land serves as the intercept; the function $\log(l(A_{it}))$ can be estimated non-parametrically; $h(t)$ can be captured by an interaction between a time fixed-effect and the non-parametric function of age; the logged sum is fixed in the cross-section and can thus be captured by time fixed effects; and idiosyncratic factors are naturally captured by the error.

Exogeneity, the critical assumption in regression analysis, would seem plausible in this formulation: It is hard to see how technological and age-related factors would be systematically associated with other, idiosyncratic factors affecting farm size. The expression in (8), however, does constrain a standard least squares formulation in two key ways: 1) it constrains the intercept to equal total land, and 2) it constrains the relationship between the year fixed effects and the non-parametric function of age. These constraints create testable implications of the model. These constraints are also crucial for tracing feedback effects between the age distribution, rents, and farm sizes, and thus are key for estimating the relative contributions of technological and demographic factors in determination of farm-size growth.

Data

The data used in this analysis are derived from the microfiles of the Agricultural Census. The Agricultural Census is conducted every five years and attempts to collect information from every farm in the United States. Farms are defined by any farm that produced or could have normally produced \$1000 in sales. In this preliminary study we only examine data from 1992, 1997, and 2002. In an anticipated revision of this paper we will also include data from 1982, 1987, and if available, 2007. To limit the influence of very large farms, many of which manage large land areas but have little production because the bulk of their land is low-value range or woodland, we limit our analysis to operations with 15,000 or fewer acres. This reduces the sample size by less than three tenths of one percent in 1992 and 1997 and less than two tenths of one percent in 2002. Mean farm sizes and weighted-mean farm sizes are reported in table 1.

For each census year, we categorized farms into 63 groups according to the age of the operator. A single group was assigned to each age between 25 and 85, accounting for 61 groups and two additional groups were assigned to farms with operators less than 25 and greater than 85. For each group in each census year we calculated each of the following statistics: 1) mean farm size (in acres); 2) acre-weighted mean farm size; 3) the percentage of farms; and 4) the percentage of total land area. These statistics are plotted in figures 1-4. Each dot represents the particular statistic for an age group and year, with different years plotted in different colors in order to differentiate them. Smooth non-parametric regression lines are overlaid each year to better illustrate patterns over time and across age groups.

Farm size conditional on age, plotted in figures 1 and 2, appears similar in 1992 and 1997. This similarity is consistent with the multiplicatively separable form of the equilibrium model as described by equations (3)-(5). By 2002, however, farm size conditional on age (using both measures) shifted up markedly across all age groups. This pattern strongly suggests technological factors interact with lifecycle factors, as in the subsequent formulation given by equations (6)-(8). The rightward shift in the age distribution of farm operators is clearly indicated in figure 3. The share of land operated by the different age groups, plotted in figure 4, mirrors the shift in the age distribution of farm operators.

Regression Results

The regression model is

$$(9) \log(L_{gt}) = \beta_0 + \beta_1 l(A_{gt}) + \beta_2 D_{t=1997} l(A_{gt}) + \beta_3 D_{t=2002} l(A_{gt}) + \beta_4 D_{t=1997} + \beta_5 D_{t=2002} + \varepsilon_{gt}$$

where the β_i are regression coefficients to be estimated, $D_{t=j}$ are dummy variables equal to 1 for year j and zero otherwise. Because there are no covariates that vary within age-specific groups, we can estimate the equation using group averages rather than individual observations, hence the subscript g rather than i . Note, however, that we will need to account for the number of farms in each age group when interpreting the coefficients below. The function $l()$ is estimated non-parametrically. Joint estimation of the fixed coefficients (β_i) and the nonparametric function $l()$ is done using backfitting: An initial

proxy for $l()$ is obtained by regressing the $\log(L_{gt})$ against A_{gt} using local polynomial regression (“loess”). Predicted values from this initial regression are then taken as given allowing for estimation of the parameters β_i . Then taking β_i coefficients as given, we solve equation (9) to give a new dependent variable:

$$(10) \quad \frac{\log(L_{gt}) - \hat{\beta}_0 - \hat{\beta}_4 D_{t=1997} - \hat{\beta}_5 D_{t=2002}}{\hat{\beta}_1 + \hat{\beta}_2 D_{t=1997} + \hat{\beta}_4 D_{t=2002}} = l(A_{gt}) + \varepsilon_{gt},$$

which we use to re-estimate $l()$ using “loess”. We continue alternating estimates of β_i and $l()$ until the estimates converge, which occurs in just three iterations. Results of the preliminary analysis are summarized in table 2 and the non-parametric estimate of $l()$ is plotted in figure 5. Note that $l()$ is normalized so that its mean value is zero.

The key testable implications of the model are that:

$$(11) \quad \begin{aligned} \beta_0 &= \log(\bar{L}) - \log\left(\sum_j \exp(l(A_{j,1992}))^{\beta_3}\right) \\ \beta_0 + \beta_1 &= \log(\bar{L}) - \log\left(\sum_j \exp(l(A_{j,1997}))^{\beta_3 + \beta_4}\right) \\ \beta_0 + \beta_2 &= \log(\bar{L}) - \log\left(\sum_j \exp(l(A_{j,2002}))^{\beta_3 + \beta_5}\right) \end{aligned}$$

Plugging in estimated values from the regressions, the right-hand side of the above expressions are 5.9185, 5.9193, and 6.0119, which compare well with the left-side values of 5.9158, 5.9205, and 6.0092. We leave a formal test of the joint equivalence to a future version of this paper.

The log-sum expression in (8) and above in (11) capture feedback effects between life-cycle factors, technological change, and land rental rates. The difference in the log sum across years is under 0.01 between 1992 and 2002. This implies that feedback effects mitigated farm-size growth by about 1 percentage point between 1992 and 2002. Since average farm size increased about 9.5 percentage points over this time frame, this implies that, without feedback effects from changes in both technology and the age distribution of operators, farms size growth would have been about 10.5 percentage points rather than 9.5.

We can evaluate direct effect of age-distribution changes by integrating $l()$ over the age distributions of in 1992 and 2002 and taking the difference. This difference equals 0.0084, or about 8.4 tenths of a percentage point. We can similarly evaluate the age-distribution feedback effects by evaluating the log-sum expression for 2002 using the age distribution profile from 1992. This calculation implies an offsetting change of -0.0068, or about 6.8 tenths of a percentage point. Combining these effects implies that changes in the age distribution affected average farm size by a net of about 1.6 tenths of a percentage point, or about 2 percent of the total change (of 9.5 percentage points).

Conclusion

Despite the clear relationship between farm size and age and shift in the age distribution, this preliminary analysis indicates little change in average farm size can be attributed to demographic changes. However, as mentioned in the introduction, the mean farm size is a poor measure of the increasing concentration of production on large farms (Roberts and

Key, 2008, forthcoming). Future extensions of this research will estimate the contributions the demographic shift and technological change to farm size growth using alternative measures such as the weighted-mean farm size. Future work could extend this analysis to include data from the 1982, 1987, and 2007 Census, which will expand the period of analysis from 10 years to 25 years, a period encompassing much greater structural change. Future work could also account for the fact that land rental markets are local and local changes in the age distribution (and by implication, farm productivity) may influence local rental markets. This preliminary analysis considered equilibrium only on a national scale. Accounting for local age-size and age distributions may yield different results.

References

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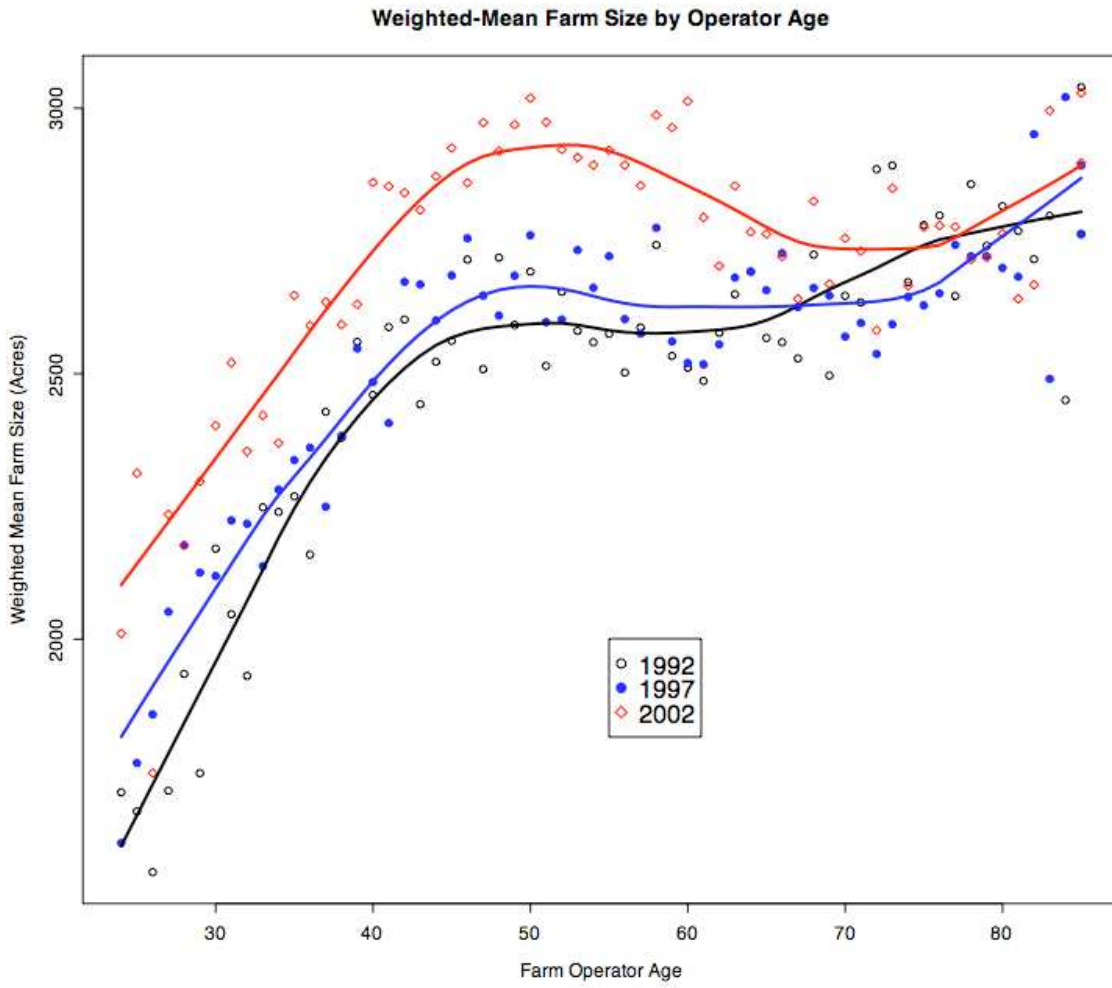
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Table 1. Mean and Weighted Mean Sizes of Farms with 15,000 or Fewer Acres.

Year	Mean Farm Size (Acres)	Weighted-Mean Farm Size (Acres)
1992	386.2	2531.7
1997	387.5	2584.7
2002	423.0	2820.6
Percent change (1992-2002)	9.5	11.4

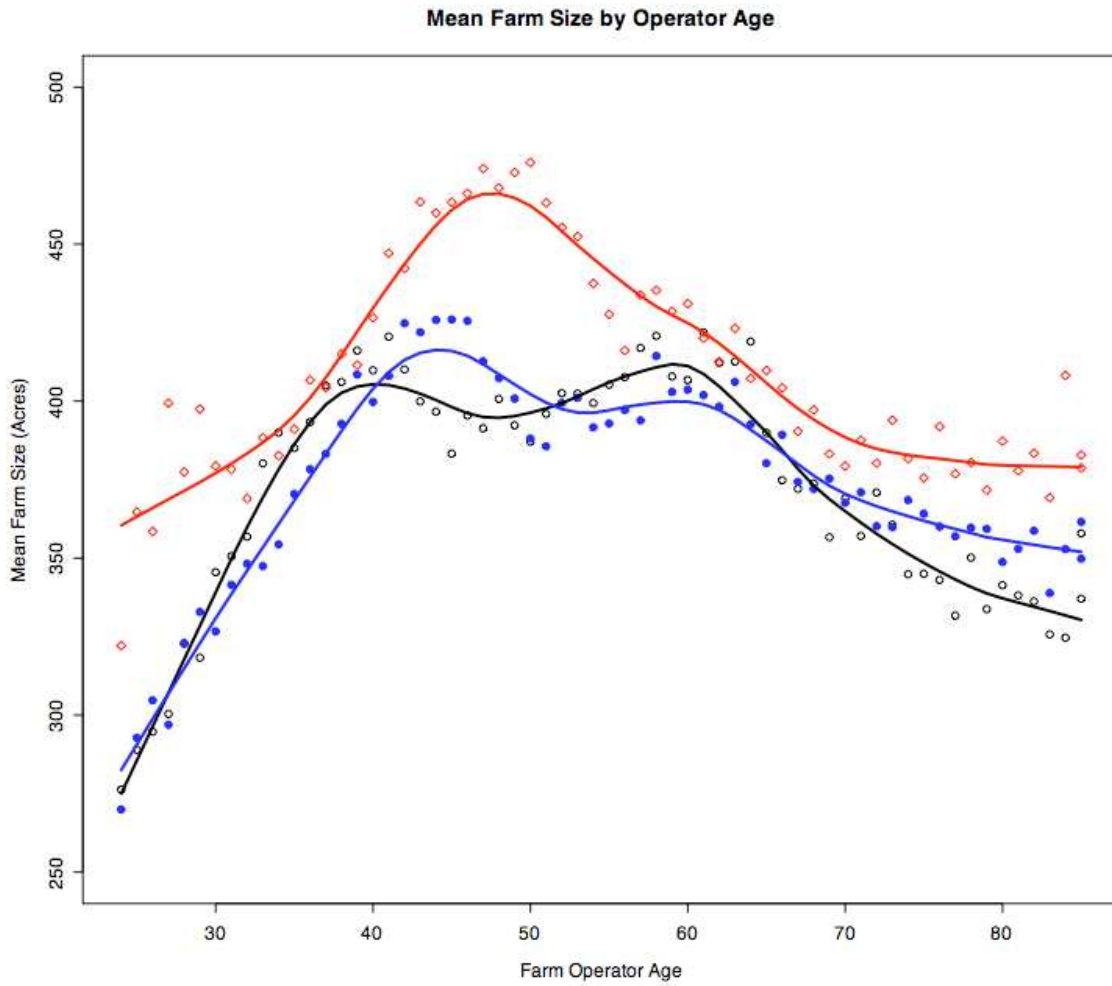
Note: Farm size refers to the amount of land owned by the farm operator plus land rented in minus land rented out. The weighted mean weights each observation by farm size.
 Source: Authors' calculation using Census of Agriculture, 1992, 1997, 2002.

Figure 1.



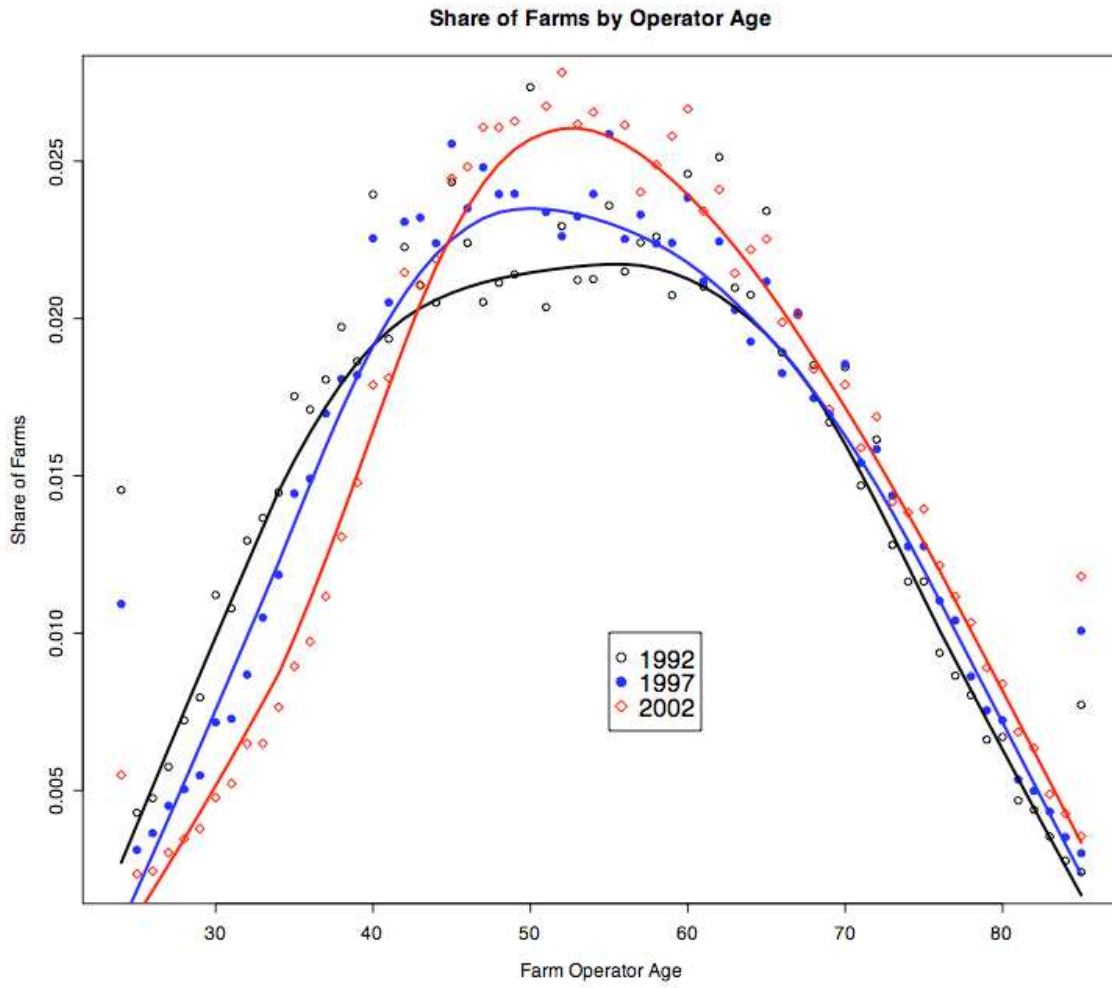
Source: Authors' calculation using Census of Agriculture, 1992, 1997, 2002.

Figure 2.



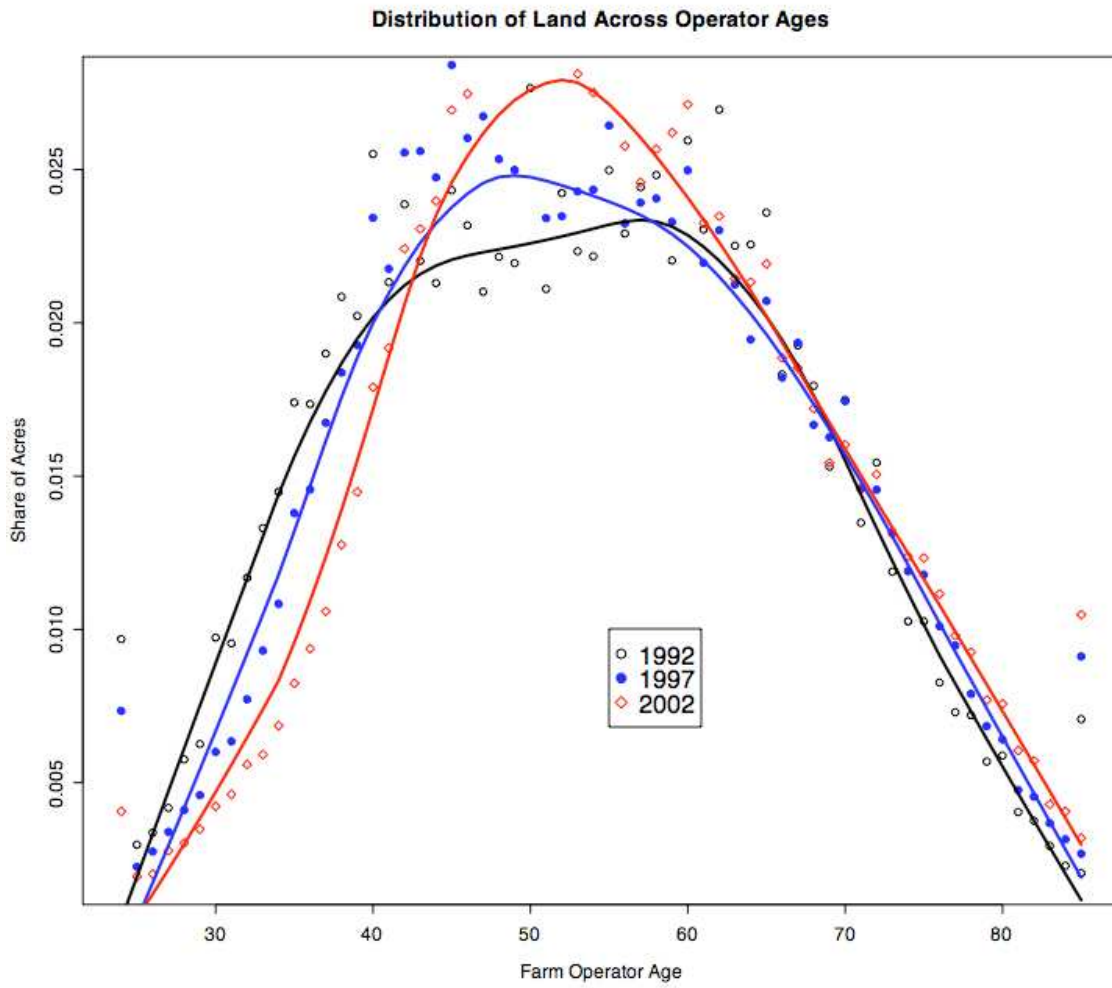
Source: Authors' calculation using Census of Agriculture, 1992, 1997, 2002.

Figure 3.



Source: Authors' calculation using Census of Agriculture, 1992, 1997, 2002.

Figure 4.

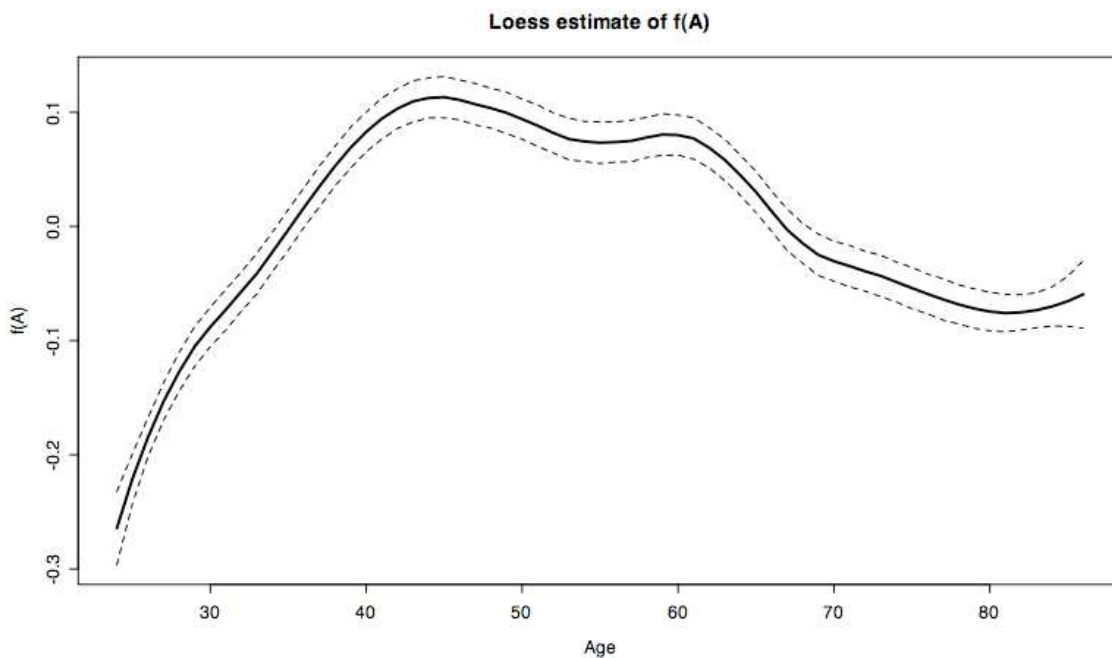


Source: Authors' calculation using Census of Agriculture, 1992, 1997, 2002.

Table 2. Summary of mean farm size regression

<i>Covariate and associated parameter</i>		<i>Estimate</i>	<i>Std. Error</i>	<i>t value</i>
Intercept	(β_0)	5.916	0.004	1386.6
$l(A_i)$	(β_1)	0.005	0.006	0.8
(Year=1997)* $l(A_i)$	(β_2)	0.093	0.006	15.5
(Year=2002)* $l(A_i)$	(β_3)	1.086	0.048	22.5
Year=1997	(β_4)	-0.050	0.068	-0.7
Year=2002	(β_5)	-0.241	0.068	-3.5
R^2 -Adj. = 0.893				

Figure 5. Nonparametric estimate of farm size-age function $l(A)$



Note: Dashed lines indicate plus- and minus- two standard errors for the estimated function

Source: Authors' calculation using Census of Agriculture, 1992, 1997, 2002.