REFEREED ARTICLE

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Farmer productivity by age in the United States

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ABSTRACT

The productivities of farmers by age group for each of the previous eight U.S. agricultural census years were estimated by Tornqvist productivity indices. Productivity increases with age, peaks at mid-life and then decreases by age for each census year. This concave productivity pattern appears to be muted in the last census years of 2007 and 2012, such that the productivity increase and then decrease is not as large as in previous census years. If older farmers had not experienced decreases in productivity, U.S. agricultural output in 2012 would have been 5.66 percent greater.

KEYWORDS: farmer age; farmer productivity

Introduction

The average age of the U.S. farmer is increasing. In the U.S. Agricultural Census of 2012, the average age of the U.S. farmer was 58.3 years of age compared to an average age of 50.5 years reported in the 1982 agricultural census. As expressed by U.S. Agricultural Secretary Vilsack at Opening Comments to the Drake Forum on America's New Farmers, August 12, 2014, "We have an aging farming population. If left unchecked, this could threaten our ability to produce the food we need – and also result in the loss of tens of thousands of acres of working lands that we rely on to clean our air and water." As Figure 1 illustrates, average farmer age has increased each census year. But does that mean we might have a reduced ability to produce the food we need if the average farmer age continues to increase? That of course depends upon whether the productivity of the older farmer is lower than the productivity of younger farmers. Farm productivity depends upon efficient use of inputs, and this may depend upon farm size as well as the application of best practices and other factors. Those factors may be correlated with age, and thus would be reflected in differences in measured productivity by age. Beginning farmers may have limited resources and thus not able to capture any economies of size until they accumulate assets in middle age. Older farmers may not keep current with new technology, suffering a decrease in productivity.

Past research by Tauer (1984, 1995), and Tauer and Lordkipanidze (2000) have shown using previous census data that there does appear to be a life cycle phenomenon in production agriculture, such that farmers increase their productivity to mid-life, but then experience a decrease in productivity as they age. Those studies used various methods to estimate productivity and data from different production years. The purpose of this current paper is to use a consistent method on each of the last 8 census years and estimate the life-cycle pattern over those years to further test whether the life cycle pattern by age exits in U.S. farming and then determine if this pattern has changed over time. I find that the life-cycle exists but may have been muted in recent census years. The reduction in productivity as a farmer ages appears to be not as significant as in the past.

Loomis (1936) introduced the concept of the life cycle of the farm and found a cyclical relationship between the age of farmers and the size of the farm, use of inputs and output. This became received theory and Harl (1982) included a life cycle diagram in his popular farm estate planning book. Gale (1994) studied farms over age and time using census data from the years 1978, 1982, and 1987 and found that mean growth rates are greatest for younger farms, although he did not estimate productivity by age. Likewise, recently Katchova and Ahearn (2015) examined farm expansion by age and also found that younger farmers tend to expand over time in contrast to older farmers. Expansion permits adoption of new technology and practices which may be conducive for increases in productivity with age.

There is empirical evidence on the productivity of farmers of various ages, because many have included farmer age in estimating the efficiency or productivity of specific farms types. In exploring multiple job holdings for instance, Goodwin and Mishra (2004) find that farm efficiency decreases with farmer age. That pattern is almost universal in the myriad of articles estimating farm level productivity and efficiency summarized by Bravo-Ureta, *et al*. 2007, in a meta-regression of farm efficiency studies.

The limited research in agriculture exclusively looking at the role of age in farmer productivity is perplexing

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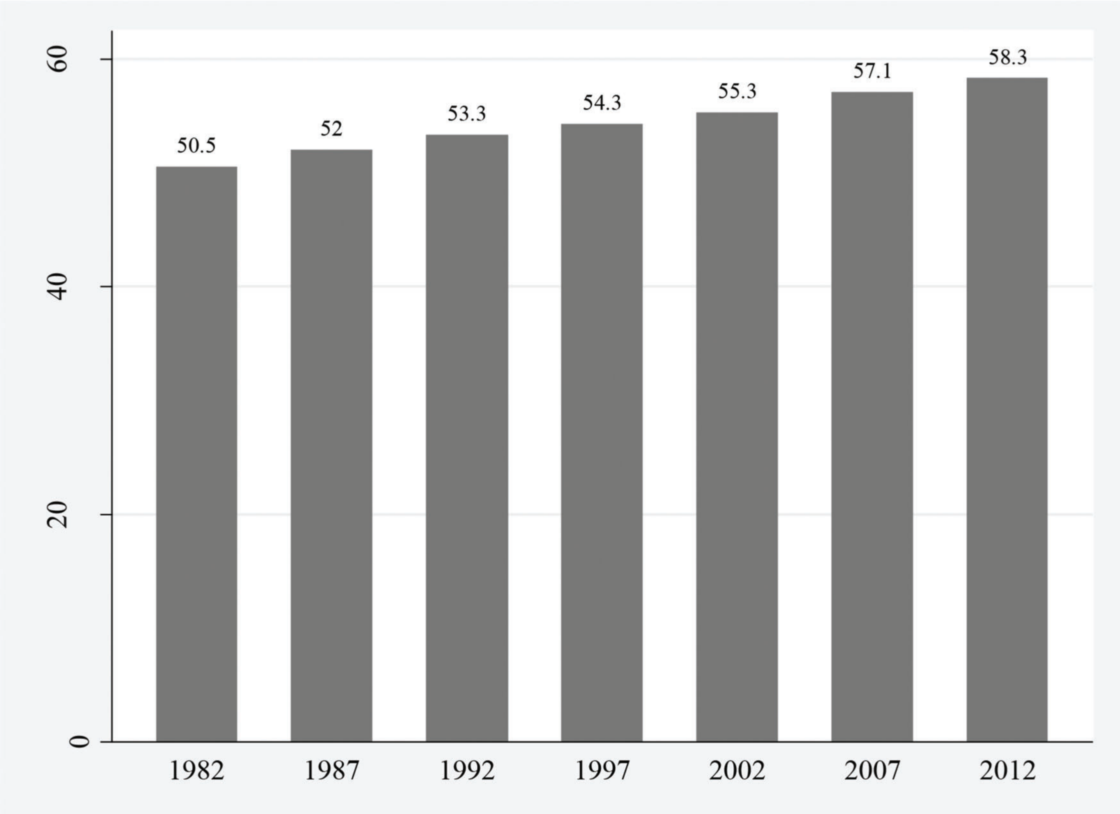

Figure 1: Average age of the principal farm operator, census years 1982-2012. Data: USDA NASS, census of agriculture

given the vast literature in labor economics estimating this relationship. The workforce in most countries and industries is getting older. A recent review of the literature by Frosch (2011), and a special section in *Labour Economics* (Bloom and Sousa-Poza, 2013), summarizes and explores some of the empirical results. Those results provide evidence of a concave relationship between productivity and age in a vast range of economic sectors.

Articles concentrating on farmer age and productivity include Tauer (1984), who estimated a production function using 1978 Census of Agriculture state level data by age group and derived marginal products of various inputs by age. He concluded that the overall productivity of the U.S. farmer was greatest at the age group of 35 to 45 years old. Tauer (1995) further estimated Tornqvist indices by age group and by U.S. region using 1987 Census of Agriculture data, after acknowledging and finding that the production function may differ by region. He likewise found a concave life cycle with a peak in efficiency, again in the middle age group of 35 to 45 years of age. Tauer and Lordkipanidze (2000) using 1992 U.S. Agricultural Census data, decomposed productivity into technology differences and efficiency indices using Data Envelopment Analysis methods. They found a life cycle pattern which varied by region, but most of that was due to differences in technology by age and less from efficiency differences by age. This implies that ageing farmers were not keeping up with technological change, but were still rather efficient in using the technology they had installed on the farm. Recently Fried and Tauer (2016) revisited age productivity using year 2012 U.S. Agricultural Census data and found that the life cycle may have become muted such that the older farmers are almost as productive as the younger farmers. They experienced a data limitation due to disclosure restriction on some inputs items in some states, mostly for the youngest age groups. This precluded them from using data from those age groups in those states, potentially biasing the empirical results. Data restriction by age at the state level has become more prevalent in recent census years as farm numbers have fallen, in order to prevent disclosure of data from any farming operation.

In this paper Tornqvist indices similar to Tauer (1995) are computed, but aggregate U.S. data by age group is used rather than state level data by age group given the large number of expense category items missing in many states due to nondisclosure rules. This allowed data from all age groups to be included in the U.S. aggregate analysis, including data that would be missing if state level data were used. The tradeoff is that state level results could not be derived, and technology may different across states. Aggregate productivity by age group is calculated for every U.S. Agricultural Census since the year 1978. All reported income and expense items were available and aggregated into productivity indices by age group. The estimated results support a concave productivity relationship over age, but the effect appears to be muted in recent census years.

Method and Data

Although there are alternative approaches to measure the productivity of farmers of various ages, such as econometrically estimating a production function or a dual function such as a cost function, or using Data Envelopment Analysis (DEA), I elect to calculate the productivity of farmers by age using the Tornqvist index of aggregated outputs divided by aggregated inputs. Diewert (1979) defined the Tornqvist total factor productivity index as exact and superlative because the index can be derived from an underlying translog production function (exact), which is a second order local approximation to any arbitrary functional form (superlative). That means that the estimates are flexible in measuring substitution between inputs and allows non-linear responses to input increases. Like any approach, the Tornqvist index is not without limitation, the major being that economic optimization (profit, revenue, or cost) must be assumed to use first order conditions from those optimizations to aggregate outputs and inputs (Good, Nadir, Sickles, 1996).

The Tornqvist is defined as:

$$T_{j,j-1} = \frac{1}{2}\sum_{i=1}^{M}\left(\frac{q_{i,j}}{rev_j} + \frac{q_{i,j-1}}{rev_{j-1}}\right) ln\left(q_{i,j}/q_{i,j-1}\right)$$

$$-\frac{1}{2}\sum_{k=1}^{N}\left(\frac{x_{kj}}{exp_j} + \frac{x_{k,j-1}}{exp_{j-1}}\right) ln\left(x_{k,j}/x_{k,j-1}\right)$$

where $q_{i,j}$ is revenue of output i for age group j and age group j-1 and rev is total output revenue, $x_{k,j}$ is expense of input k for age group j and age group j-1 and exp is total expenses. Typically, the terms $ln(q_{i,j}/q_{i,j-1})$ and $ln(x_{k,j}/x_{k,j-1})$ are quantities of outputs and inputs rather than output revenues and input expenditures. Quantities or prices are not collected or reported in the Census reports; outputs are reported as revenues and inputs as expenditures. Thus it was not possible to use quantities unless prices are further collected to convert revenues and expenditures into quantities. However, it not unreasonable to assume that in any given Census year, the output prices and input prices faced by each age group were identical. An individual younger farmer may have sold a crop at a higher price than an individual older farmer, but there is no reason to expect that all young farmers sold their crops at a higher price than all old farmers. The same would be true in the purchase of inputs. If these identical prices were collected and used to convert revenue or expenditure into quantities, the output or input quantity ratio would be identical to the revenue and expenditure ratios, respectively, resulting in no change in the computed Tornqvist index. As a consequence, revenues and expenditures are used rather than quantities in the output and input ratios, with identical prices assumed across age groups.

However, if the assumption of identical prices across ages is not valid, then the results would reflect differences in productivity due to price differences as well as quantity differences. If young farmers in the earlier year census years as a group where better marketers, from say a use of cells phones to keep abreast and react to market prices, then those younger farmers as a group would have higher receipts because of prices in addition to output differences, and that would be correctly reflected in higher productivity. The same would occur if they paid less for inputs.

The index can be computed between any adjacent age groups by using the output and input quantities of the two age groups. Unlike comparing Tornqvist indices across regions or countries, this index is transitive between age groups similar to an index between time periods, so the index can be chained to the youngest age group to determine the productivity of each age group relative to the youngest age group.

There have been advances in the decomposition of productivity indices into components dealing with various types of economic efficiencies as well as scale effects (O'Donnell, 2010; O'Donnell, 2012). I elect not to implement these decompositions given the aggregate nature of Census data used, which are U.S. state farm averages by age group.

The U.S. Federal Government completes an agricultural census of all farmers every 5 years. The last agricultural census was completed for the production year of 2012. Previous to that year census data were collected for the years 2007, 2002, 1997, 1992, 1987, 1982 and 1978. Individual farm data are not reported; rather data are summarized and reported by state and for the U.S., with some data reported at the county level. Of interest for this research are the data summarized by decimal age group for farmers who indicated that farming was their principal occupation. Although those data are summarized at the state level, to protect the confidentiality of farmers, some receipt and expense items are not disclosed for some age groups in some states, precluding complete state level analysis. As the number of especially younger farmers have declined over succeeding census years, comprehensive analysis at the state level was not plausible. Instead, data summarized for the entire U.S. by age group of operators whose principal occupation was farming were used.

The six age groups are farmers under the age of 25, farmers from the age of 25 to 34, farmers from the age of 35 to 44, farmers from the age 45 to 54, farmers from the age of 55 to 64, and farmers over the age of 65. Only data of farmers indicating that farming was their principal occupation were used. However, many of these operations are multiple operator farms, with many of those being multiple generational farms where children are farming with their parents, and in some cases also with grandparents. As shown in Figure 2, a smaller ratio of farmers under the age of 25 are the principal operator of multiple operator farms, which might be expected since an older parent might be the principal operator. Also a smaller ratio of the farmers over the age of 65 are the principal operator of a multiple operator farm, because they may have already turned the reigns over to a younger child. Unfortunately, multiple operated farms are not separated from sole operated farms in the published census data by age group, and therefore it was not possible to look only at the sole managed farms over the various age groups. The question is whether the recorded principal operator is indeed the principal operator making the major or final decision in a multiple operated farm. It may be that in some instances a true young principal operator may be deferring to his elder, and listing the elder as the principal operator, when in fact the young operator may be the principal operator. It may also be possible that a true older principal operator may decide that the younger operator should be listed as the principal operator. The reporting situation is simply not known, so we assume that the correct principal operator is identified correctly on the census survey.

Also shown in Figure 2 are the number of principal operators who are women by age group in the year 2012.

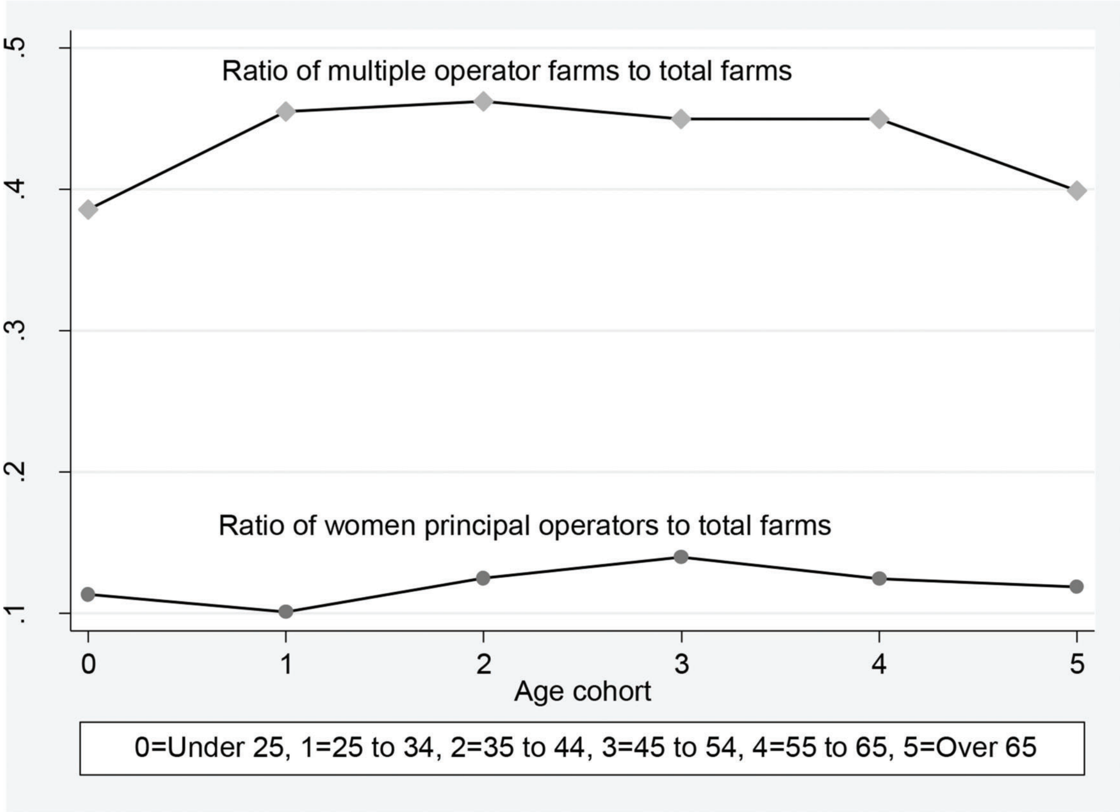

Figure 2: Ratio of multiple operated farms to total farms and ratio of women principal operated farms to total farms

The number of farms operated by women ranged from a low of 10 percent in the age group age of 25 to 34, to a high of 14 percent in the age group of 45 to 54. Eleven percent of the farm operators in the youngest age group were women. Women constituted 12 percent of the farm operators over the age of 65.

The various crop and livestock categories as shown in Table 1 are the major revenue and expense categories reported in census publications. These were actual sales and expenses that occurred during the production year of the census year rather than production and input use. For individual farms, production and sales in any year may be significantly different given inventory change decisions, but differences in production and sales should be muted over the entire population of U.S. farmers in any census year. Even if some age group consistently sold output after fall harvest rather than store the crop for sale into the following year, for instance, that event would still record consistent crop sales in any year, subject to aggregate weather effects.

Over the eight census years some slight changes were made in the reporting of some revenue and expense items. Examples include listing aquaculture as a separate revenue item in later census years when in the earlier census years aquaculture was embedded in the category of other livestock. Another change was separately listing hay as a commodity in the early years but later combining hay with other crops in later census years. These changes are noted in Table 1. Regardless, all commodity sales and farm income sources are included as output, including government payments. Government payments were included under the assumption that often production changes were required to receive these payments, and without those changes the payments would not have been received. Producers also had to meet the definition of a farmer to receive agriculture transfer payments.

Some expenses listed in the census, such as rent and depreciation, were not directly included as inputs, but rather indirectly included as a charge to the market value of real estate and machinery. Rent expenses only occur if land is rented rather than owned, and the proportion of land rented may vary by age group. As an alternative, a fixed interest rate was assessed to the market value of the real estate, both owned and rented by the farmer. Depreciation was indirectly estimated as a percent of the market value of machinery. Also interest expense is dependent on financial leverage so was not included, but is implicit in the rate charged to real estate and machinery. Finally, although farmers by age group do report various amounts of days of work off the farm (rather than the number of days they worked on the farm), all indicated that their principal occupation was farming, so it was assumed that all farmers work the necessary hours required to operate the farm business. Family labor is not recorded in the Census unless it was paid a wage, in which case it would be included in hired labor. If any age cohort uses more non-reported unpaid family labor then that would produce an upward bias in their estimated productivity.

Revenue from outputs were aggregated into one output by using a Tornqvist aggregator based upon average sales per farm. Average expense per farm were similarly aggregated into one input using the Tornqvist aggregator. Productivity differences were measured between adjacent age groups. Productivity of each age group was then indexed to the youngest age group of farmers under the age of 25. Thus, the productivity of the farmers under the age of 25 are shown as equal to 1.00

Table 1: Receipt and expense items from U.S. agricultural census to be aggregated into a Tornqvist productivity index for each age group over various census years

Item	Notes
Grain sales	Includes corn, wheat, soybeans and other grains
Cotton sales	Cotton and cotton seed
Tobacco sales	Tobacco
Hay sales	In later years hay included in other crops
Vegetables sales	Vegetables, melons, potatoes and sweet potatoes
Fruit sales	Fruit, tree nuts, and berries
Nursery products sales	Christmas trees in other farm income
Other crops sales	Some years included hay
Poultry sales	Poultry and eggs
Dairy sales	Milk from cows
Cattle sales	Cattle and calves
Hog sales	Hogs and pigs
Sheep sales	Sheep, goats, wool, mohair, and milk
Other livestock sales	Aquaculture, horses and mules
Government payments receipts	Government agricultural payments
Other farm income	Custom work performed and farm tourism
Livestock purchases	Both breeding and feeder livestock
Feed purchases	For all livestock
Seed purchases	Seeds, plants, vines, and trees
Fertilizer purchases	Fertilizer and lime
Chemical purchases	All
Fuel purchases	Fuel and oil
Electricity purchases	For the farm
Hired labor costs	Paid by farmer
Contract labor costs	Paid to contractor for farm labor
Repair costs	Supplies, repairs and maintenance
Custom work costs	Machinery hired with labor included
Miscellaneous expenses	All other expenses
Real estate costs	0.05*Real Estate Market Value
Machinery costs	0.10*Machinery Market Value

Note that interest, depreciation, property taxes and rent are not included as direct farm expenses to avoid double counting of expenses, since an opportunity cost is applied to all capital items regardless of whether these are rented or owned, or financed with debt vs equity capital.

for all census years, and the productivity of the other age groups are in reference to the youngest group. A productivity index of 1.15 would indicate that an age group is 15 percent more productive than those farmers under the age of 25.

Results and Discussion

The results support a concave relationship between age and productivity where there is first an increase and then a decrease in productivity as the age of the farmer increases. The results in Table 2 and summarized in Figure 3 show the only exception to this pattern is the census year 1987, where the age group of 55 to 64 years of age shows an increase in productivity over the previous age group of 45 to 54 years of age. In all census years, except for the year 1982, the age group 25 to 34 was more productive. In all census years except again for 1982, the age group 35 to 44 years of age was more productive than farmers under age 25. The farmers from age 35 to 44 were more productive than farmers from the age group of 25 to 34 age group in half of the census year, mostly the earlier years. The farmers in the age group of 45 to 54 were more productive than the farmers under the age of 25 except for the census years of 1987 and 1992, but were less productive than one age group younger except for the year 1978. The farmers aged 55 to 64 were less productive than the farmers under the age of 25 in five of the eight census years, and less productive than the farmers aged 45 to 54 except for the year 1987. Farmers over the age of 65 were less productive than all of the other age groups in every year. Thus one can conclude that the productivity of farmers is generally greatest at the age groups of 25 to 34, or 35 to 45, but then decreases by age group, with the farmer aged 55 and older generally less productive than the farmers under the age of 25.

Tauer (1995) had previously discussed the possible reasons for this concave age productivity pattern. Younger farmers are inexperienced and may begin with less productive capital than older farmers. By age 25 to 34 they have gained experience and may have begun to acquire more productive capital such as new equipment. Productivity then erodes after age 55 as older farmers may fail to adopt new technology and their capital stock is not replenished. This life cycle pattern with respect to productivity is not encouraging as the average farmer continues to age as shown in Figure 1.

However, it is interesting to note that the concave life cycle may becoming muted over time. This was concluded by Fried and Tauer (2016), who estimated Malmquist productivity indices by state for each age group. However, they were forced to drop many younger age groups from their analysis because of data unavailability due to nondisclosure restrictions, potentially biasing their estimates. Figure 3 plots the productivity of the various age groups by year with a line placed through the various age group productivities for the last census year of 2012. Although that is still a concave age productivity cycle with a peak at the age group of age 35 to 44, it appears that the productivity relationship with age is not as concave as previous census years. The increase in productivity from under age 25 to age 25 to 34 for year 2012 is not as great as in previous years, and the decreased productivity for age 45 to 54 is minor. The productivity decrease of those farmers over the age of 65 in 2012 is the second lowest of the census years, with the lowest productivity decrease for the oldest farmers occurring in census year 1978. This muted productivity of first an increase and then a decrease is also displayed in the census year of 2007, and may be due to the changing nature of farming. Technology changes have continued to make farming less physical. Mechanical devices often perform tasks once done by hand labor. Hours may still be long but may not be as physically exhausting when those hours are spent in air conditioned or heated tractors that drive themselves with GPS units.

What if older farmers had not experienced a decrease in their productivity as compared to peak age productivity? Table 3 summarizes the impacts. If the oldest three age groups of farmers had remained as productive as those farmers from age 35 to 44, then 2012 U.S. agricultural output would have been 5.66 percent greater. If all farmers had increased their productivity to the same level as the most productive farmers age 35 to 44,

Table 2: Tornqvist productivity indices by year and age group with indices relative to the under 25 age group for each year

Age	Census year								Average
	2012	2007	2002	1997	1992	1987	1982	1978	
Under 25	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
25 to 34	1.040	1.037	1.054	1.163	1.107	1.015	0.983	1.031	1.054
35 to 44	1.065	1.072	1.054	1.144	1.080	0.954	0.981	1.056	1.051
45 to 54	1.044	1.050	1.022	1.110	1.038	0.935	0.953	1.058	1.026
55 to 64	1.008	0.986	0.961	1.077	1.008	0.963	0.938	0.952	0.987
Over 65	0.928	0.885	0.857	0.969	0.909	0.799	0.826	0.910	0.885

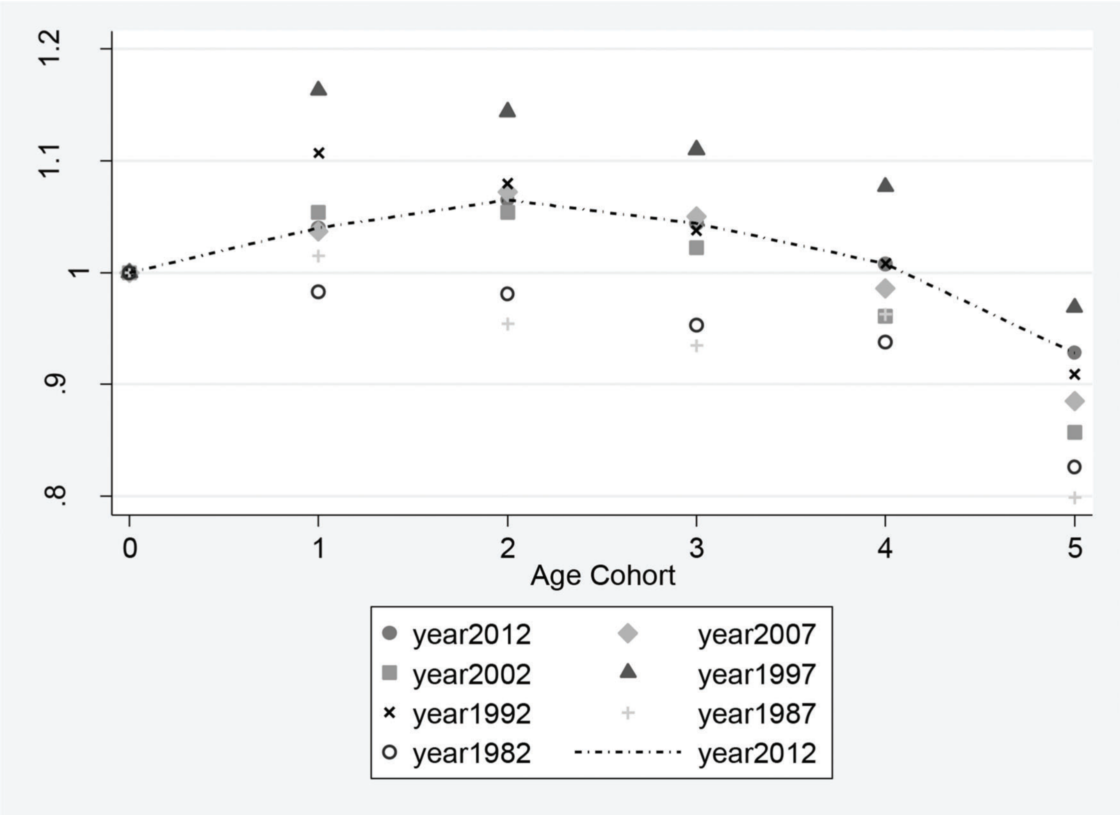

Figure 3: Productivity of farmers by age group for various census years

Table 3: Increase in U.S. agricultural output given productivity enhancements of older and all farmers

Age group	2012 productivity	2012 output (in $1,000)	Output if farmers over age 45 increase productivity to peak productivity of 1.065	Output if all farmers increase productivity to peak productivity of 1.065
Under 25	1.000	1,004,732	1,004,732	1,070,040
25 to 34	1.040	15,593,301	15,593,301	15,968,140
35 to 44	1.065	44,573,767	44,573,767	44,573,767
45 to 54	1.044	98,724,744	100,710,587	100,710,587
55 to 64	1.008	111,707,027	118,023,793	118,023,793
Over 65	0.928	77,722,823	89,196,990	89,196,990
Total		349,326,394	369,103,170	369,543,316
Percentage increase in output			5.66%	5.79%

including those farmers younger than age 35, then 2012 U.S. agricultural output would have increased 5.79 percent. This increase is not much greater than if only older farmers increased their productivity because younger farmers are reasonably productive, but more importantly, they do not produce much of U.S. agricultural output.

Conclusion

It is clear that there still exists a productivity life cycle in U.S. agriculture, such that the productivity of the average U.S. farmer first increases with age and then decreases with age. However, the increase in productivity is only about 5 percent greater at mid-life compared to farmers under the age of 25, and only decreases 1 percent at age 55 to 64. Unfortunately, the productivity falls 11 percent for those farmers over the age of 65. These are averages over the eight census years and individual census year patterns vary somewhat with the most recent census showing productivity only falling 7 percent for those farmers over the age of 65. If all farmers in the year 2012 were as productive as the most productive age group of 35 to 44, then U.S. agricultural output would have been greater by 5.79 percent.

About the author

Loren Tauer is a professor in the Charles H. Dyson School of Applied Economics and Management at Cornell University where he teaches and conducts research in agricultural finance and production economics.

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