ARTICLE IN PRESS

Food Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Food Policy

journal homepage: www.elsevier.com/locate/foodpol

Farm size and productivity growth in the United States Corn Belt☆

Nigel Key

U.S. Department of Agriculture, Economic Research Service, 1400 Independence Ave., SW, Mailstop 1800, Washington, DC 20250-0002, United States

ARTICLE INFO

Keywords:
Agricultural productivity growth
Total factor productivity
Scale economies
Farm structure

JEL classifications:
D24
Q12
Q15
Q18

ABSTRACT

In recent decades, agricultural production in the U.S. has continued to shift to large-scale operations, raising concerns about the economic viability of small and midsized farms. To understand whether economies of size provided an incentive for the consolidation of production, the study estimates the total factor productivity (TFP) of five size classes of grain-producing farms in the U.S. Heartland (Corn Belt) region. Using quinquennial Agricultural Census data from 1982 to 2012 the study also compares TFP growth rates across farm sizes to gain insight into whether observed productivity differences are likely to persist. The finding of a strong positive relationship between farm size and TFP suggests that consolidation of production has contributed to recent aggregate productivity growth in the crop sector. The study estimates the extent to which sectoral productivity growth can be attributed to structural change versus other factors including technological change. The study also explores some tradeoffs associated with policies that raise the productivity of small versus large farms.

1. Introduction

Over the past several decades, there have been pronounced structural changes in the U.S. farm sector – with production shifting steadily to larger operations. Between 1982 and 2007, the midpoint farm size – the size at which half of all land is on bigger farms and half is on smaller farms – almost doubled from 589 to 1105 acres (MacDonald et al., 2013). At the same time, the midpoint acreage more than doubled in each of the five major field crops: corn, cotton, rice, soybeans, and wheat. Additionally, the share of output from farms with sales of at least $1 million increased from less than 30% in 1987 to over 60% in 2007 (Sumner, 2014).

The shift in production to large farms has raised questions about the economic viability of small and mid-sized producers, and the rural communities that depend on these farm households. These and other concerns have helped spur Federal efforts to target resources toward smaller-scale operations through loan, risk management, marketing, and educational programs (USDA, 2017). The extent to which farming is characterized by economies of size – that is, how much average unit costs decrease as farm size increases – is likely to influence the rate and extent of future consolidation.[1] The first objective of this study is to estimate the total factor productivity (TFP) and unit costs of crop farms of different sizes to understand how productivity and costs vary. This analysis focuses on operations located in the U.S. Heartland (Corn Belt) region that specialize in major field crops.

To gain further insight into the long-run economic viability of small farms, the study also estimates how productivity has changed over time for crop farms of different sizes. It is possible that some recent technological advances (e.g., very large combine harvesters, precision agriculture technologies, improved seed varieties) have raised the productivity of larger operations more than smaller operations. This has implications for whether small farms can persist as viable economic units. Economies of size give large-scale operations a competitive advantage – allowing production at a lower unit cost. If new technological advances favor larger operations, economies of size will increase over time and likely hasten the demise of small family farms. On the other hand, if small farms can increase productivity at a faster rate than large farms, it may be possible to reduce smaller farms' competitive disadvantage and potentially slow or even reverse the consolidation of production. This study is the first to inform this issue by estimating long-run trends in productivity for crop farms of different sizes.

The second objective of this study is to estimate how much of the

☆ I would like to thank Nicholas Rada, Keith Fuglie, and two anonymous reviewers for helpful comments on the manuscript. The views expressed in this paper are those of the author and should not be attributed to the Economic Research Service or USDA. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

E-mail address: nkey@ers.usda.gov.

[1] Economies of size is defined by how average (unit) costs change when production increases. More precisely, a firm is said to display economies of size if a one percent increase in output results in a less than one percent increase in average costs. Economies of scale – a closely related to but distinct concept – is defined by how output changes when all inputs are increased in the same proportion. That is, a firm is said to display increasing returns to scale if a one percent increase in all inputs results in a more than one percent increase in output. The concepts are closely related as a cost-minimizing firm exhibits increasing returns to scale if and only if it simultaneously exhibits increasing returns to size (Chambers, 1988, pp. 21–77).

https://doi.org/10.1016/j.foodpol.2018.03.017

0306-9192/ Published by Elsevier Ltd.

Please cite this article as: Key, N., Food Policy (2018), https://doi.org/10.1016/j.foodpol.2018.03.017

past aggregate productivity growth can be attributed to structural change (changes in the farm size distribution) versus other factors, including technological change. The recent consolidation of agricultural production has coincided with substantial growth in agricultural productivity: between 1982 and 2012, aggregate TFP increased by 46% – an average annual growth rate of about 1.3% (ERS-USDA (2017)). In explaining the drivers of this productivity growth, most research has focused on technical progress and the role of research and development in promoting technological advances (e.g., Wang et al., 2015; Alston et al., 2010). Little research has examined the contribution of structural change to aggregate productivity growth. If large farms are more productive than smaller farms, as we find in this study, the widespread shift in production towards larger farms could explain a portion of the aggregate productivity growth observed over the past several decades (Huffman and Evenson, 2001). Additionally, understanding the extent to which structural change has explained past productivity growth can shed light on future productivity potential. If the scope for further consolidation of production is now less that it was in the past – because most output is now produced by large farms – then aggregate TFP growth will likely slow in the years ahead unless the rate of technological progress increases.

The third objective of this study is to better understand the relationship between farm size and aggregate productivity growth. The paper develops a new method for estimating aggregate agricultural productivity growth based on the share of production of farms in different size categories, shifts in the distribution of production across farms of different sizes, and changes in the productivity of different sized operations. This allows us to estimate how targeted policies that raise the productivity of farms of a particular size would affect aggregate TFP growth. Results show that targeting small operations would result in much less aggregate productivity growth than similar policies targeting larger operations, mainly because larger farms had higher average sales shares. However, the relative cost-effectiveness of targeted policies, in terms of raising aggregate productivity growth, depends on whether the policy costs are proportional to farm output or the number of farms targeted.

2. Methodology

2.1. Empirical framework

There are two main approaches that can be used to compare the productivity *change over time* of farms of a similar size. If panel data were available, one approach is to assign farms to time-invariant size categories – for example, according to a farm's initial size. Calculating TFP change for each farm would allow for a straightforward comparison of average productivity change across farm size categories. If stochastic production function or data envelope analyses were performed, it would be possible to disaggregate TFP change for each size category into technical change, and technical and scale efficiency change (Färe et al., 1994; Orea, 2002).

This approach has significant shortcomings if a substantial portion of farms transition between size categories over the study period: e.g., some small farms become large and some large become small. Using a sales-based farm size measure, Burns and Kuhns (2016) showed that over five years about 42% of midsize farms transitioned into either small or large farms. They also report five-year transition rates for small and large farms ranging between 21% and 33%. When farm size is fluid, as is likely the case over long periods of time, placing farms in time-invariant categories does not permit a valid comparison of the productivity growth of similarly-sized operations.

Another drawback of this approach, because it relies on panel data, is the potential for sample attrition bias. U.S. crop farms are characterized by five-year attrition rates of about 35–50%, depending on the size of the operation, crop specialization, and operator's age, among other factors (Key and Roberts, 2006).[2] Hence, only a fraction of farms would continue to be observed over a long period, such as the 30-year span considered in this analysis. The farms that remain in business over a long period would likely be very different from the population as a whole – and would have different levels of productivity. Hence, assertions about the population as whole from a sample of surviving farms could suffer from sample attrition bias unless this can be adequately addressed by the empirical model.

The second main approach for making productivity growth comparisons across farm size is to categorize observations by size in each year. This cohort approach can use repeated cross-section or panel data to estimate changes in productivity by farm size groups (Morrison Paul et al., 2004). If the surveys are representative in each period, this approach is not vulnerable to sample attrition bias.

The drawback to this cohort approach is that the farm size categories are fixed, so estimates of scale efficiency change for the farms in each size category will be close to zero (except, perhaps, for the largest farm size category, which typically is unbounded from above). Hence, this approach mostly ignores an important source of aggregate productivity growth: economies of size resulting from a shift in the farm size distribution.

To illustrate the limitation of the cohort approach consider a simple example where there are two farm size categories, small and large, and size economies such that small farms have a TFP index value of 1 and large farms have a TFP of 2. Also assume for simplicity that there is no technical change over the study period, but there is a shift in production from small to large farms. If initially 50% of output is produced by each type of farm, then aggregate TFP in the first period is 1.5 ($=0.50\cdot 1 + 0.50\cdot 2$). If production shifts so that in the second period small farms produce 25% of output and large farms produce 75%, then aggregate productivity increases to 1.75 ($=0.25\cdot 1 + 0.75\cdot 2$). Because there was no technical change, a cohort analysis that compared the productivity change of farms of the same size would estimate zero productivity growth for small and large farms, even though aggregate productivity increased substantially. Hence simply comparing the productivity of farms in the same size category does not reveal the contribution of increasing farm size to aggregate productivity growth.

In this study, we develop a framework for estimating the contribution of structural change to aggregate productivity growth using cohort data. Let the aggregate TFP in any period be approximated by the sales-weighted average TFP of S size categories:

$$TFP = \theta_1\cdot TFP_1 + \theta_2\cdot TFP_2 ... + \theta_s\cdot TFP_s ... + \theta_S\cdot TFP_S, \tag{1}$$

where θ_s is the share of total sales produced by farms in category s and is the average TFP of farms in category s. It follows that the change in the aggregate TFP between two periods is:

$$\begin{aligned}\Delta TFP = {} & (\Delta\theta_1\cdot\overline{TFP}_1 + \Delta\theta_2\cdot\overline{TFP}_2 ... + \Delta\theta_s\cdot\overline{TFP}_s ... + \Delta\theta_S\cdot\overline{TFP}_S) \\ & + (\Delta TFP_1\cdot\bar{\theta}_1 + \Delta TFP_2\cdot\bar{\theta}_2 ... + \Delta TFP_s\cdot\bar{\theta}_s ... + \Delta TFP_S\cdot\bar{\theta}_S),\end{aligned} \tag{2}$$

where Δ indicates the change between periods and the overbar represents the average of the two periods. The first term in parentheses is the contribution to aggregate TFP change from the change in the farm size distribution. The second term in parentheses is the contribution to aggregate TFP from the change in TFP from farms within each size category, where $\Delta TFP_s\cdot\bar{\theta}_s$ is the contribution from the TFP change of farms in size category s.

Note that the change in TFP for each size category, ΔTFP_s, could be decomposed into changes in scale efficiency, technical efficiency and technical change. However, since the size categories are fixed, scale

[2] Attrition rates are high in studies that use Census of Agriculture data in part because farms can only be tracked over time with an operator identification number. When an operator retires from farming and sells his farm business or passes it on to his children the operator ID will often change and this will be recorded as a farm exit. Additionally, the attrition rate is high because farmers who do not respond to the Census will be classified as having exited.