ESTIMATING THE MOST EFFICIENT FARM SIZE FOR CROP PRODUCERS

Sub Theme: Knowledge & Information

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Abstract:

Economic theory suggests that farms will experience increasing economies of size up to some number of hectares. After that, there is likely a range of hectares where economies of size are constant before starting to increase. Finding that range where economies of size are constant will be where firms earn the most profit per hectare and are most likely to survive in the long run. This paper examined the net returns per hectare for over 200 farms in central Kansas. Regression analysis was used to predict the adjusted net farm income per hectare based on either the number of hectares or the log of hectares. The expectation was that there were enough farms examined to show both the increasing and decreasing economies of size. However, the resulting R squared was very low because of a large variability in net returns per hectare for the smaller farms. A linear regression line fit the data just as well as a nonlinear model. This could indicate that most farms in the examination were already at an efficient size.

Keywords: *Economies of size, Profitability, Efficiency, Hectares, Crop production*

Introduction

Economic theory suggests that economies of size exists for many firms but that at some point, these size advantages go away as the firm simply becomes too large to manage (Rasmussen, 2013). For agricultural grain producers, this means that farms need a certain number of hectares to take advantage of modern equipment and technologies. These assets often have a high initial cost but can help increase profitability over older technology if the costs can be allocated over a large enough number of hectares. However, at some farm size, allocating labor and equipment becomes increasing difficult, costs start to increase, and the economies of size go away. There is likely a range of hectares where costs per hectare are minimized or close to minimized and that results in producers maximizing their per hectare profitability.

The purpose of this paper is to examine the per hectare profitability of grain farms to determine which size of farm is most efficient so that producers, lenders, and other agricultural decision makers can set farm size goals. A set of grain farms from

Kansas was used in the analysis and a regression analysis was performed to determine the best fit of profitability per hectare. This line showed the size a farm needs to be to be most efficient.

Economies of size is the concept that the average cost per hectare decreases (or the per hectare profit increases) as the size of the farm increases. Economies of size can exist for two reasons. First, producers can spread a level of fixed costs over more hectares of production. Second, variable costs can be obtained at lower prices per unit because of volume discounts. Economies of scale and scope are related concepts where the proportion of inputs stays constant and can produce gains as well (Sheng, Zhao, Nossal, Zhang, 2014).

Economies of size are important because finding the farm size where the costs per hectare are minimized (or profits per hectare are maximized) will help ensure the survivability of a farm. In a long-run competitive industry like agriculture, prices for outputs will typically be pushed down to the minimum of the average total cost curve. If producers are not at an efficient farm size, they will be unprofitable. Finding this optimal farm size is also important to lenders and policy makers as they try to guide farms toward this farm size.

Background

Several studies have examined farm size and profitability. In particular, Illinois and Kansas have examined this topic as these two states have large farm analysis programs with multi-year data. Schnitkey and Lattz (2003) found that farms less than 480 hectares were less efficient than larger ones. Once farms reached 480 hectares, costs were constant. Schnitkey and Lattz attributed the economy of size gains to labor and machinery efficiencies. There were no size efficiencies for variable costs of production. Kern and Paulson (2011) used the same Illinois data set but focused on profitability per and found that small farms can be just as profitable as larger farms on a per hectare basis. Kern and Paulson did find a size advantage to larger farms but only during periods of low commodity prices.

The previous two studies focused on comparing costs and returns for farm by dividing the samples into two groups. Other approaches have focused on the entire set of farms at once. Langemeier and DeLano (1999) used DEA analysis to find an advantage for larger farms. Duffy (2009) used census data to show that farms did display some economies of size but that the range of economies of size were over a short range and then economies of size became constant over a large range of farm sizes.

Methodology

To estimate the hectares where the farm size is most profitable on a per hectare basis, the net farm income per hectare is calculated for a set of grain farms. With the net income per hectare as the dependent variable and farm size as the independent variable a regression is run to determine how the net income per hectare responds to farm size changes. Ideally, a non-linear model would be needed as the hypothesis about optimal farm size is that farms show a range of increasing returns to size, then a range of constant returns to size, and then finally a range of decreasing returns to size. In other words, the regression line should resemble an inverted "V" pattern where the point could actually be a range rather than a single point (i.e., maybe an inverted “U”).

In this study, data from the Kansas Farm Management Association (KFMA) was used. The KFMA program has been collecting computerized financial and production data since 1973 although the program actually goes back further than that. The KFMA program currently has approximately 2,500 farms across the state of Kansas. Each farm works with a KFMA economist to collect and verify data. The economist provides not only tax advice but also management advice for a farm. Typically, a KFMA economist will work with 100 farms. The data collected from this program is more accurate than that collected by a typical tax preparer as KFMA economists meet with their clients multiple times during the year. Data from these farms is certified before it goes into the research database and approximately 1,500 of these 2,500 farms were certified as useable farms. In addition, the presence of livestock farms can skew net economies of size when since livestock and grain farms have different cost and returns per hectare. Thus, only crop farms were used in the analysis (about two-thirds of the useable farms)

The measure of efficiency used in this study was adjusted Net Farm Income (NFI) per hectare. Often, the minimum cost per unit is used as the measure of efficiency. However, without a constraint for either yields or profits, a producer could simply have a low cost of production by not using as many inputs. By using the adjusted NFI per hectare we should get the same results as focusing on minimizing the cost of production with a yield constraint. The focus on NFI does require an assumption that producers receive equivalent prices for their grain. This study attempted to allow for output price variation as discussed below. Kern and Paulson (2011) also focused on profitability per hectare as opposed to costs in their analysis of farm size.

This study examined the three-year average of net farm income per hectare as the efficiency measure. A single year's profits per hectare could be problematic as rainfall differences and other weather factors could distort the per hectare profits of a given producer. By using an average of three years, these weather factors should even out across a region. Also, the three-year average flattens out any price differences that producers might receive for their crop. That is, a producer who happens to sell his or her crop at the high price point in one year is unlikely to repeat that the next year.

The NFI per hectare measure used in the study is a better measure of profitability that either taxable net farm income or accrual net farm income. KFMA farms in this study start with accrual net farm income which is a much better measure of yearly net farm income than cash accounting net farm income. In addition, the reported net farm income is also based on management depreciation as opposed to tax depreciation. Depreciation expenses often distort reported net farm income in the United States because accelerated depreciation laws exist that often allow a producer to write off the entire purchase price in the year purchased. KFMA reported net farm income controls for this by using "management" depreciation. Management depreciation uses a formula that depreciates the purchased asset at a much slower rate than any of the available tax rules. Management depreciation is an attempt to match the book value of the asset to the actual market value of the asset.

Land control and farm equity levels are a consideration when estimating the optimal farm size. Farms with lower equity levels will likely have lower net income per hectare as these farms use more debt to control assets. The extra interest from using more debt capital makes it difficult to compare farms with low debt to farms with high debt. Likewise, farms with more rented hectares will likely have a lower income per hectare as these farms must pay a landlord. To control for these differences, the net farm income per hectare is adjusted by subtracting a charge to long-term equity capital (i.e., land). This adjustment should put all farms in the study on equal footing. Schnitkey and Lattz (2003) used a similar adjustment. Whether a producer is controlling land through a rental arrangement (and paying a landlord), owning land but using debt capital, or owning land with a producer’s equity and then adding a charge to this equity, producers should be more directly comparable. The Farm Financial Standards Council uses a similar process when calculating Return on Assets as the calculation adds back in interest expense. This adjustment to ROA makes it possible to compare farms with low debt to high debt.

The last adjustment to the model was to divide the state into three regions. Kansas experiences large differences in rainfall when moving east to west across the state. The western part of Kansas typically receives less than half the rainfall of the eastern part. The drier parts of the state typically earn less income per hectare (and have lower per hectare expenses) since yields are lower and the region cannot be farmed as intensively. To control for these differences and make comparisons meaningful, the analysis is divided into three regions. Analyses were run on all three regions but this paper will only focus on the central Kansas as the results were similar for all three regions. When dividing the state into three regions there were 253 farms in central Kansas, 266 farms in eastern Kansas, and 72 farms in western Kansas. These numbers represent the Kansas grain farms that had useable data from 2013, 2014, and 2015.

The regression analysis consisted of two set or regressions for each region and also for two timeframes. In both models, the adjusted net farm income per hectare (adjusted to account for management depreciation and adding a charge for long-term equity) was the dependent variable. The independent variable was the number of hectares. A log of hectares was also examined. Analyses were performed on both the three-year average net farm income from 2013 to 2015 and also the three-year average net farm income from 1974 to 1976. The 40-year difference is used to examine any changes in economies of size across time.

Results

Farms in the Kansas Farm Management Association program have nearly doubled in size over the past 40 years. As shown in Figure 1, the average KFMA farm in central Kansas has expanded from 300 hectares to 600 hectares. The percentage of rented hectares also changed from 60% to 70%.

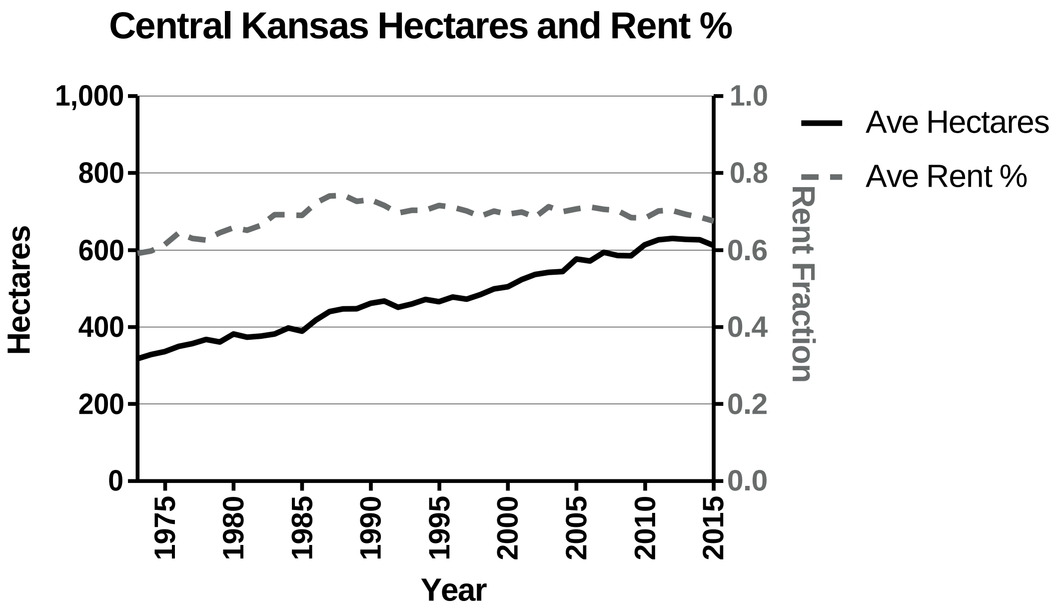

Figure 1. Changes in Farm Size and Percentage of Land Rented for Central Kansas

Figures 2 and 3 show the cumulative distribution of crop hectares for central Kansas. In 1976, over 80% of the farms had less than 500 hectares. Only a few farms had more than 800 hectares. By 2015, 50% of the farms had less than 500 hectares while 20% had more than 800 hectares.

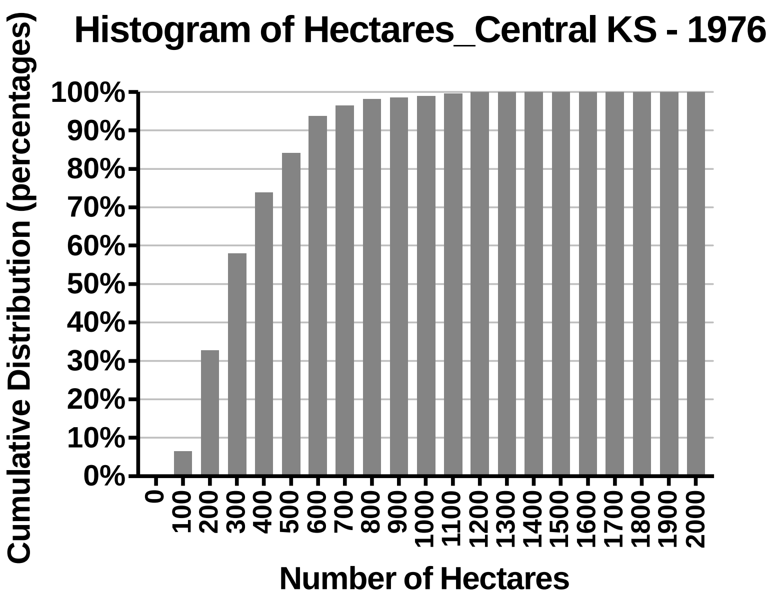

Figure 2. Cumulative Distribution of Hectares for Central Kansas in 1976

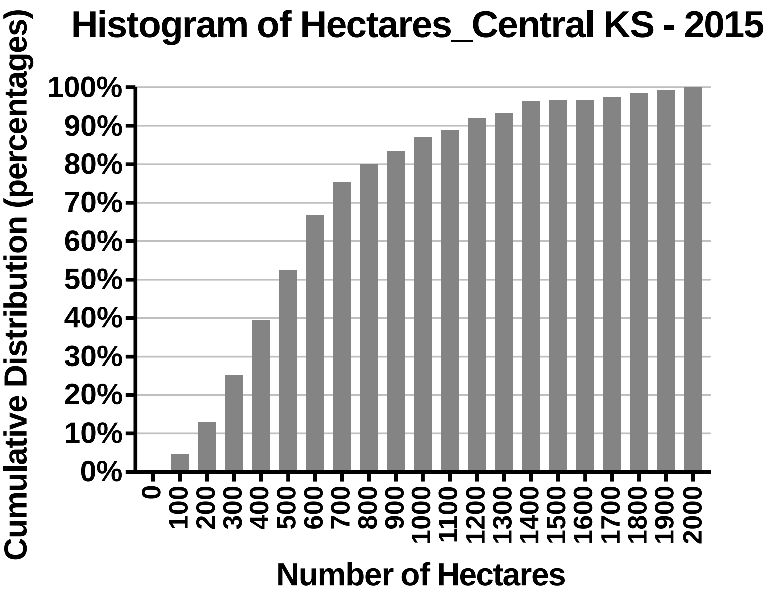

Figure 3. Cumulative Distribution of Hectares for Central Kansas in 2015

Regression results from regressing adjusted NFI per hectare against hectares is shown in Figure 4. Figure 5 shows the results when using a log of hectares instead of just hectares. Figure 6 shows the results of regressing adjusted NFI against hectares for 1976 data.

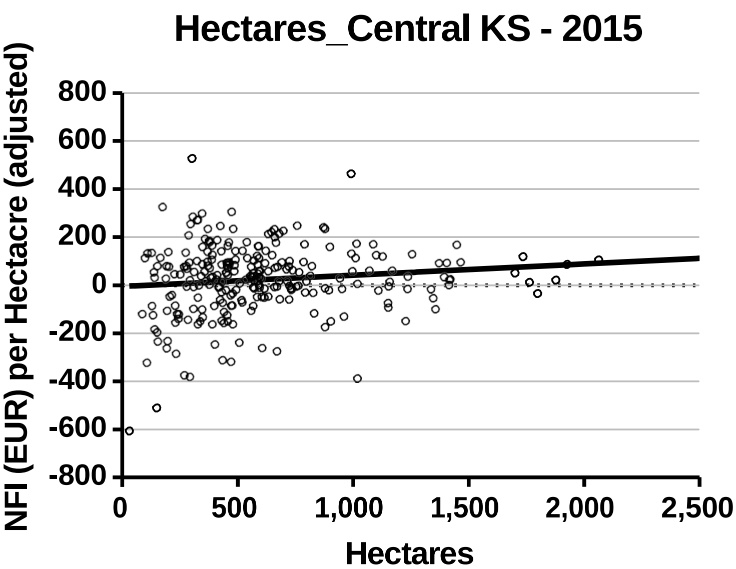

Figure 4. Scatterplot of NFI against Hectares for 2015

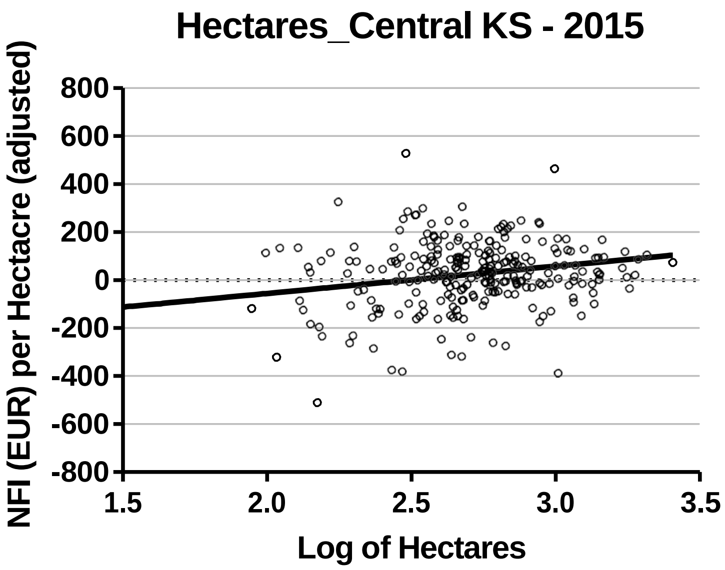

Figure 5. Scatterplot of NFI against Log of Hectares for 2015

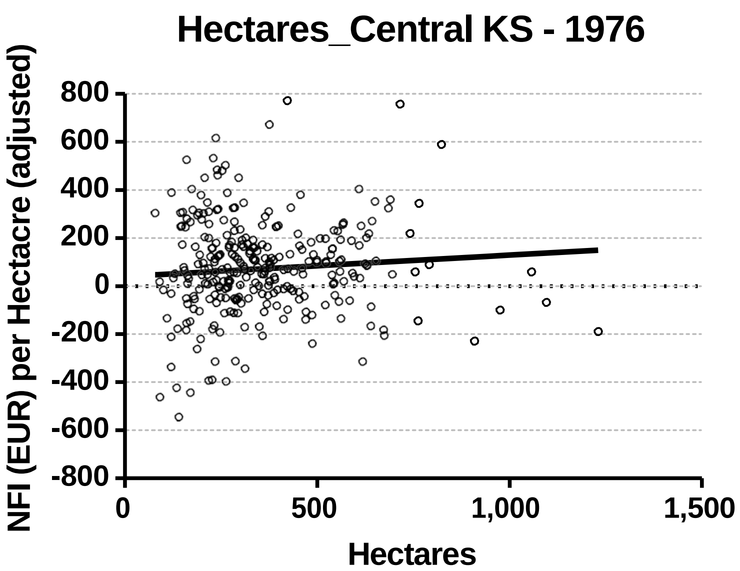

Figure 6. Scatterplot of NFI against Hectares for 1976

A visual inspection of the regression seems to indicate a low fit. The actual R squared is low too. The regression with log hectares has the best fit at 0.05. The other two regions showed similar results. The results from 1976 have similarly low R squared values.

Discussion

Because the average farm size in the KFMA program has more than doubled over the last 40 years, farmers may have seen their economies of size change. Modern equipment is larger than ever before and can cover more hectares per day. This equipment is expensive and to lower the fixed costs per hectare, these machines need to be run on as many hectares as possible. Thus, farms have become bigger to maximize their per hectare profits.

The low fit of the regression models indicates there are other factors driving the net farm income per hectare other than just farm size. Using a regression approach to find economies of size may not be the best approach as there is still unaccounted variability. Smaller farm sizes have more variability in the net farm income per hectare than do larger farms.

While the models have a low fit, there is at least a hint that larger farms may be more efficient as the linear regression has an upward sloping curve. The hypothesized inverted “V” or “U” shape to the regression curve could be there but there is enough variability in the results that such a curve linear shape cannot be shown.

Another possibility for not see the expected regression line is that KFMA farms have figured out the most efficient size already and are operating at that size. In other words, the farms shown may be along that size range where returns to size are constant. Finally, the KFMA database may not have the very small farms or the very large farms where net farm income per hectare is not optimal.

Conclusion

It appears that the most efficient size of Kansas farms follows a large range of hectares. The KFMA set of farms may simply not include any farms that are so large that their cost per hectare is higher than other farms in the program. If there were farms like this, the competitive nature of agriculture where producers are often see prices at the low point of the average total cost curve may have caused inefficient farms to go out of business.

The KFMA program does include some smaller farms and these farms show a range of possible net farm income per hectare. Some of the smaller farms appear to be just as efficient as the larger farms. This might indicate there are ways around some of the issues with modern equipment and spreading those costs over a large number of hectares. The use of custom field operations is one possibility for avoiding the necessity of purchasing modern but expensive equipment.

A final factor affecting the variability of results is management ability. Producers will have varying levels of skills when it comes to farm management. One farmer might be very efficient with 3,000 hectares while another farmer might struggle with 1,000 hectares. One possibility of future work is to add a variable for producer age and experience.

References

Duffy, M. (2009) Economies of Size in Production Agriculture. *J Hunger Environ Nutr*, 4, 375-392.

Kern, M. & Paulson, N. (2011) Profitability and farm size on grains farms in Illinois. Farmdoc Daily,

Langemeier, M.R. & DeLano, F.D. (1999) Characteristics of highly efficient farms. Western Agr. Econ. Association Annual Meetings. July 11-14, Fargo, ND,

Paulson, N.D. & Kuethe, T.H. (2015) Trends in Farm Size and Potential Demand for Farm Management Association Services. *Journal of the ASFMRA.*

Rasmussen, S. (2013) Economies of Scale and Size Production Economics: The Basic Theory of Production Optimisation. Springer Berlin Heidelberg, Berlin, Heidelberg.

Schnitkey, G. & Lattz, D. (2003) Size Economies on Illinois Grain Farms. Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, Farm Business Management Factsheet FEFO, 03-10.

Sheng, Y. et al. (2015) Productivity and farm size in Australian agriculture: reinvestigating the returns to scale.