Relative Competitiveness of Crop/Livestock Farms: A current perspective

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A current perspective on the economic performance of smaller family farms.

Changes in technological and market forces and urbanization pressures have changed the structure of U.S. agriculture. The impacts of this structural transformation on the economic health of small family farms include declines in profitability and competitiveness. An increasingly strong move toward larger farms has raised questions about the long-term economic viability of the small family farm. Associated recent trends toward greater farm (especially livestock) concentration, and corporate industrialization and contracting out of production, also have raised questions about the future survival of remaining small independent operations.

Observed production patterns in the U.S. agricultural sector suggest that these technological and structural changes are likely associated with economies from both scale of production and output composition, so that larger and more diversified farms are increasingly more productive or efficient than small farms. Kumbhakar et al. (1989, dairy farms), and Kumbhakar and Heshmati (1997, grain farms) and Sharma et al. (1999, hog farms) provide evidence that this hypothesis may be true in the context of technical efficiency. Sumner (2104) provides a more recent perspective of technological drivers boosting production on larger farms. These findings suggest the importance of efficiency impacts from scale and composition changes, and the potential to enhance our understanding of farms' performance patterns by further evaluation of these productivity drivers.

Family farms include any farm where the majority of the business is owned by the operator and relatives of the operator. Nonfamily farms do not meet that requirement (Hoppe 2013). In this analysis we chose to focus on specialized livestock operations on the one hand and crop/livestock operations with livestock but not specialized, i.e. more 'traditional" with producers often growing both crops and livestock.

Using farm-level data from USDA's Agricultural Resource Management Survey (ARMS) and a transformation function approach we estimate returns-to-scale and technical efficiency of farms and compare the relative performance of specialized crop/livestock family operations (with value of production of livestock of $250,000 (VPL) [1] or more) and "traditional" family oriented type crop livestock operations with (VPL) of less than $250,000. The $250,000 value represents close to the average value of output for the sample analyzed, i. e. $313,000 and with sales averaging $290,000. Note that average sales of all farms in Iowa was $230,000 in 2013 (Love, The Gazette Iowa Ideas 2013). We include farms located in four primary corn producing states in the Heartland: Illinois, Indiana, Iowa, and Ohio[2] To achieve population estimates of the frontier performance measures, relating family farms defined in Table 1, to all other farms we included limited resource farms and nonfamily farms both also defined in Table 1 in our econometric and DEA estimates and in our summary statistics in Tables 2 and 3 and in the Appendix Table 1. Also, note that the $250,000 value of livestock production break used in this analysis (in real 2002 dollars) populates all of the crop/livestock groups with shares greater than ten percent and ranging 11.5 to 15.3 percent as shown in Table 2. This suggests that the measures of economic

[1] The dollar values reported in Tables 2 and 3 are deflated to 2002 dollars using the indexes of prices received and paid from USDA's *Agricultural Statistics*.

[2] Analysis is done to compare the performance of "traditional" family oriented crop/livestock operations with specialized crop/livestock family operations in the Heartland by VPL<=$250,000 versus VPL>$250,000 by type of small, medium or large farm. For purposes of this analysis *small farms* are defined as all Farming occupation/low sales AND Farming occupation/moderate sales farms using Hoppe's typologies as a base from Table 1 (Hoppe and MacDonald 2016). Similarly, *medium farms* are defined as Family farms, and *large farms* are defined as Large family farms AND Very large family farms from Table 1.

performance reported in Table 3 can be used to compare the competitiveness of crop/livestock farms across groups.

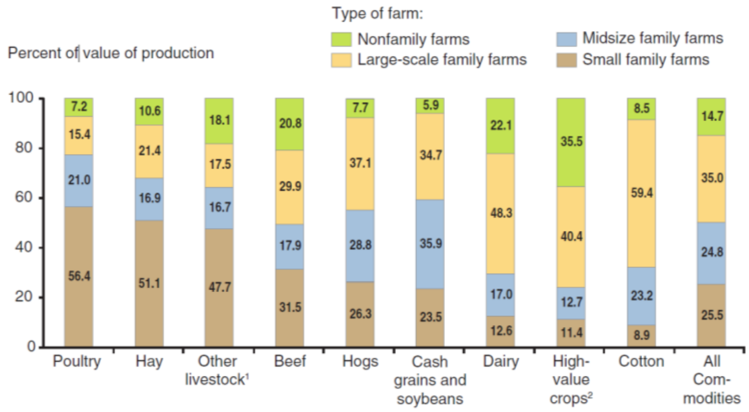
The study proceeds as follows. In the first section we provide background on structural shifts in corn/livestock farms in recent years and on the importance of off-farm income on crop/livestock farms. In the second section we provide methodology used in this study. Data and Methods are presented next. Results are discussed next, followed by a summary and conclusions section.

Background on Traditional or Family Farms

Structural Shifts

Recent work by Hoppe indicates that in 2011 small and medium sized family farms produce a substantial share of crops and livestock (Figure 1). For example, small (<$350,000 in nominal sales) and medium ($350-999,000 in nominal sales) sized family farms, respectively, produced 26.3 percent, and 28.8 percent of total production of hogs in 2011, over half of the total. And, in 2011 they produced close to 60 percent of total cash grains and soybeans. Recent work by (Nehring et al. 2013) indicates that the bulk of independent production of hogs was in the Heartland-half of total production. Both independents and contractees indicated positive household income; i.e. off-farm income was important to the financial survival of their operations. Off-farm income is also important on crop farms (Fernandez et al 2008, Nehring et al. 2013), cow-calf operations (Nehring et al. 2013) and dairy operations (Nehring et al. 2017).

Figure 1. Distribution of the Value of Production for Selected Commodities, 2011.



Source; Hoppe Structure and Finances of U.S. Farms: Family Farm Report. 2014 Edition.ERS, EIB 132 December 2014, Washington, DC. Definitions of all size classes are laid out in Table 1.

In recent work focusing on on crop farming (MacDonald et al. 2013) found that large farms now dominate crop production in the United States. Although most cropland was operated by farms with less than 600 crop acres in the early 1980s, today most cropland is on farms with at least 1,100 acres, and many farms are 5 and 10 times that size. MacDonald et al. ask “What implications do these structural shifts have for family farms?”

Importance of Off-farm Income

As on-farm and off-farm activities compete for scarce managerial time in U.S. farm operator households, economic decisions (including technology adoption and other production decisions) are likely to shape and be shaped by time allocation within the farm household (Fernandez-Cornejo, 2007). While the importance of off-farm income to economic well-being of all U.S. farmers is widely acknowledged (Boisvert and Chang 2005, Gardner 2005, Mishra et al. (2009, 2012), however, it is less clear if off-farm work is actually helping farm households to improve their economic performance across farm sizes and types of enterprises. In particular, because of the higher managerial labor required in livestock production (e.g., dairy) compared to crop production, off-farm work decision is likely to have a larger impact on farm-level scale efficiency of livestock farms than of crop farms. However, the effect of off-farm work on household-level scale efficiency is less clear because it depends on the relative proportion of on-farm and off-farm activities by farm operators and spouses on the farms (Fernandez-Cornejo, 2007).

In a study of U.S. farms, Nehring, Fernandez-Cornejo, and Banker (2005) using 1995-2003 data, found that larger farms are generally more efficient than smaller farms in transforming farm inputs into outputs given the technology at their disposal. But focusing on farm inputs and outputs alone is misleading because off-farm income-generating activities can be important in determining economic performance of the farm household. Previous research (e.g. Fernandez-Cornejo et al. 2007) has shown that when off-farm activities are included in the model, farm household-level scale efficiencies are higher than farm-level scale efficiencies, across all farm sizes as shown in Nehring and Fernandez (2005) and Fernandez-Cornejo et al. (2007). Further, scale efficiency gains from integrating off-farm work into the output portfolio are relatively greatest for smaller farms (Fernandez-Cornejo, 2007). As a result, household-level efficiencies of smaller farms are comparable to farm-level efficiencies of larger farms. This suggests that households operating small farms have partially adapted to shortfalls in farm-level performance by increasing their off-farm income. In this paper, we show these changes by typology—recently updated by Economic Research Service (ERS) of the United States Department of Agriculture (USDA) to reflect commodity price inflation and the shift of production to larger farms—as defined in Table 1 (USDA 2013).

Measuring Corn/Livestock Farm Productivity

The corn/livestock farms included in our cross-country sample use multiple factors to produce corn, other crops, and livestock. Hence, it is desirable to model these processes using a function that accounts for the production of multiple outputs with multiple inputs. Following Sauer and Morrison-Paul (2013), we use a transformation function to represent the most output producible given the feasible production set. This function in general form can be written as $0=F(\mathbf{Y},\mathbf{X},\mathbf{T})$, where **Y** is a vector of outputs, **X** is a vector of inputs, and **T** is a vector of (external) shift variables, which reflects the maximum output producible from a given input vector and existing external conditions. By the implicit function theorem, if $F(\mathbf{Y},\mathbf{X},\mathbf{T})$ is continuously differentiable and has non-zero first derivatives with respect to one of its arguments, it may be specified (in explicit form) with that argument on the left hand side of the equation.

Accordingly, we estimate the transformation function $Y_1 = G(\mathbf{Y_{-1}},\mathbf{X},\mathbf{T})$, where Y_1 is the primary output of corn/livestock farms (crops and livestock) and $\mathbf{Y_{-1}}$ is the vector of other outputs, to represent the technological relationships for the corn/livestock farms in our sample (off-farm income). Note that this specification does not reflect any endogeneity of output and input choices, but simply represents the technologically most Y_1 that can be produced given the levels of the other arguments of the transformation function. This is important because in the alternative input (output) distance function approaches, for example, one input (output) is required for normalization in order to impose linear homogeneity. This raises issues not only about what variable should be expressed as ratios with respect to the left-hand side variable, but also about econometric endogeneity because the right-hand side variables are expressed as ratios with respect to the left-hand side variable. See Mas-Colell et al. (1995), page 128–29 for a fuller discussion and a graphical presentation of the transformation function set and transformation frontier.

We estimate the transformation function $Y_{M,it} = F(\mathbf{Y}_{NM,it,}, \mathbf{X}_{it}, T)$, where Y_M is farm production (livestock and noncorn crops) measured in real dollars for farm *i* in period *t* and $\mathbf{Y}_{NM}$ are corn production and off-farm income measured in real dollars. Vector **X** indicates inputs to include labor, misc expenses, capital, and land (measured in real dollars [3]). We have quality adjustment measures for land. Land is measured as an annualized flow of services from land (the quality adjusted price by state using data from ERS productivity accounts multiplied times acres operated, annualized over 20 years at a discount rate of 5 percent) (see Nehring et al. 2006 for details on the methodology used to compute the annualized service flow of land). The inputs were labor, fertilizer, pesticides, fuel, miscellaneous, land, crop-specific expenses, and livestock-specific expenses. Variable T represents year.

A number of flexible functional forms may be used to represent production technology, such as the translog, quadratic, and generalized linear. As suggested by Diewert (1973), the generalized linear functional form is used for our study to avoid variable calculations that would lead to zero netput values (which would occur with functional forms that include logarithms). As shown by Sauer and Morrison-Paul (2013), for farm *i* in period *t*, the functional form for our study is:

1) $$Y_{M,it} = F(Y_{NM,it}, X_{it}, T) = a_0 + 2a_{0NM}Y_{NM}^{0.5} + \sum 2a_{0k}X_k^{0.5} + a_{NMNM}Y_{NM} + a_{kk}X_k + \sum a_{kl}X_k^{0.5}X_l^{0.5} + \sum a_{kNM}X_k^{0.5}Y_{NM}^{0.5} + b_T T + b_{TT}TT + \sum b_{KT}X_k^{0.5}T + b_{NMT}^{0.5}T + \varepsilon_{it}.$$

To represent and evaluate the production structure, we compute the first-order elasticities of the transformation function. The first-order elasticities in terms of the farm output Y_M represent the (proportional) shape of the production possibilities frontier (given inputs) for output Y_{NM} and the

[3] All these variables are deflated to 2002 dollars using the indexes of prices received and paid from USDA's *Agricultural Statistics*.

shape of the production function (given other inputs and Y_{NM}) for input X_K – or output trade-offs and input contributions to farm output, respectively. That is, the estimated output elasticity with respect to the corn and off-farm outputs, $\varepsilon_{M,NM} = \partial \ln Y_M/\partial \ln Y_{NM} = \partial \ln Y_M/\partial \ln Y_{NM} *(Y_{NM}/Y_M)$, is expected to be negative as it reflects the slope of the production possibilities frontier, with its magnitude capturing the marginal trade-off between farm output and corn production and off-farm outputs. The estimated output elasticity with respect to input k, $\varepsilon_{M,K} = \partial \ln Y_M/\partial \ln X_K = \partial Y_M/\partial X_K *(X_K/Y_M)$, is expected to be positive, with its magnitude representing the (proportional) marginal productivity of X_K .

Returns to scale (RTS) may be computed as a combination of the Y_M elasticities with respect to the farm and non-farm outputs and inputs. For example, for a production function, RTS is defined as the sum of the input elasticities to, in a sense, reflect the distance between isoquants. Similarly for a transformation function, such a measure must control for the other output(s). Formally, RTS is defined for the transformation function as $\varepsilon_{M,X} = \varepsilon_K\ \varepsilon_{M,K}\ /(1-\varepsilon_{M,NM})$. Technical efficiency is defined as the ratio of the observed output to the frontier output that could be produced by a fully efficient firm. Thus, technical efficiency of a farmer is between zero and one and is inversely related to the inefficiency effect. The TE (technical efficiency) "scores" are estimated as TE = $\exp(-u_i)$. It is assumed that the inefficiency effects are independently distributed and u_i arise by truncation (at zero) of the exponential distribution with mean m_i, and variance σ^2.

Data and Methods

We use U.S. farm-level ARMS survey data from the 2002 through 2015 production. ARMS is an annual survey covering farms in the 48 contiguous States, conducted each year by USDA, and designed to incorporate information from both a list and area frame. The list and area frame components are incorporated using a system of weights that are used to properly weight all data. Inferences for the states and regions must account for the survey design by using weighted observations. The farm-level data are used in an innovative way. We link fourteen annual ARMS surveys to form a pooled time-series cross-section, assuming that the survey design (developed annually) for each year is comparable.

For the US, data on crop/livestock farms is used in the Heartland the data are from USDA's Agricultural Resource Management Survey (ARMS) for 2002-2015, and include 27,023 crop/livestock farms. The states included are Illinois, Indiana, Iowa, and Ohio. These states account for close to 40 percent of planted corn acres in the United States.

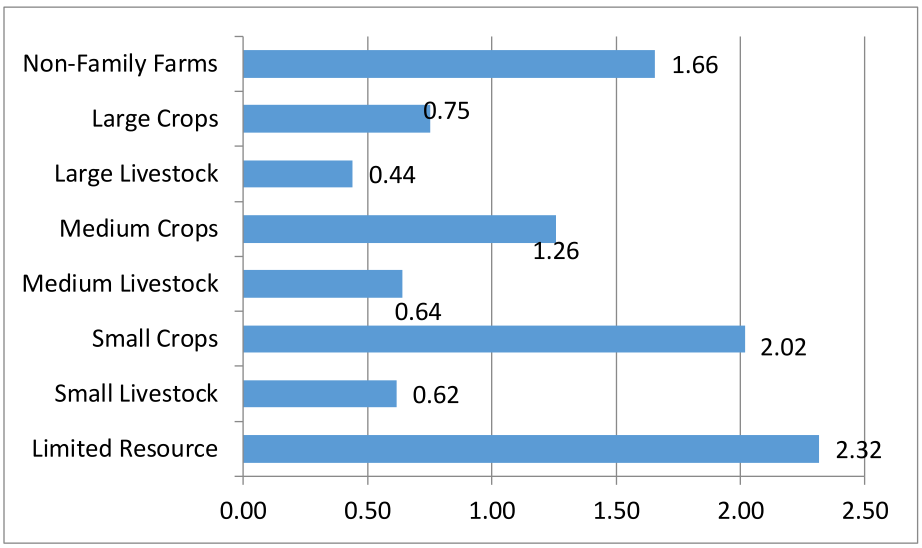
Results

The transformation function estimates for the Heartland resulted in >50% of the estimated parameters being significant at the $P \leq 0.10$ level. In addition, the calculation of output elasticities (expected negative signs) and input elasticities (expected positive signs) generally resulted in correct signs. These results are available on request from the authors. Overall, the estimated transformation functions fit the data quite well.

Tables 2 and 3 present the summarized scale and technical performance results by group and summary statistics over time. We find that large crop/livestock farms generally outperformed smaller farms using most economic measures. This is particularly the case with respect to profitability and RTS, but not TE. We discuss each of these in more detail as follows.

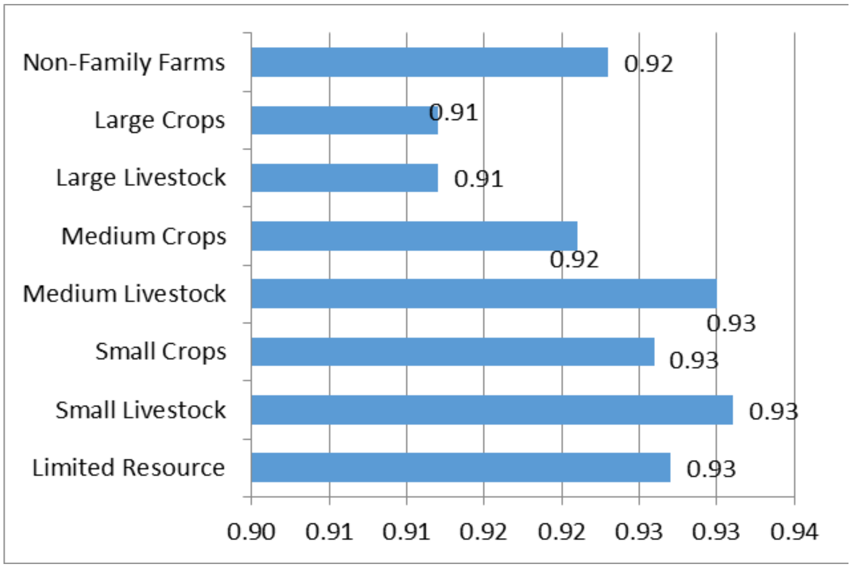
Returns to Scale and Technical efficiency: We find that in for the small and medium typologies that RTS trended downward as farm sized and as size of specialized crop/livestock operation increased, indicating greater scale efficiency with more intensive with higher animal units per farm and on larger crop/livestock farms.

Figure 2. Returns to Scale



We also find that for small and medium farms RTS decreased strongly, indicating greater scale efficiency for operations exploiting off-farm income opportunities. We find that for the small and medium typologies that technical efficiency was higher than for larger farms, but not generally statistically different from technical efficiency levels for larger farms. Future research categorizing high versus low performers (by specialized crop/livestock and "traditional" crop farm) by technical efficiency level would perhaps be informative on technical and economic drivers of high performance (see Nehring et al. 2017).

Figure 3. Technical Efficiency



Net Return on Assets

Net return on assets generally trended upward as farm size increased, suggesting greater profitability for larger-scale operations. Note that if we measure return for the household returns (including off-farm income and interest income) relative to household assets, that returns become generally positive.

Figure 4. Net returns on assets

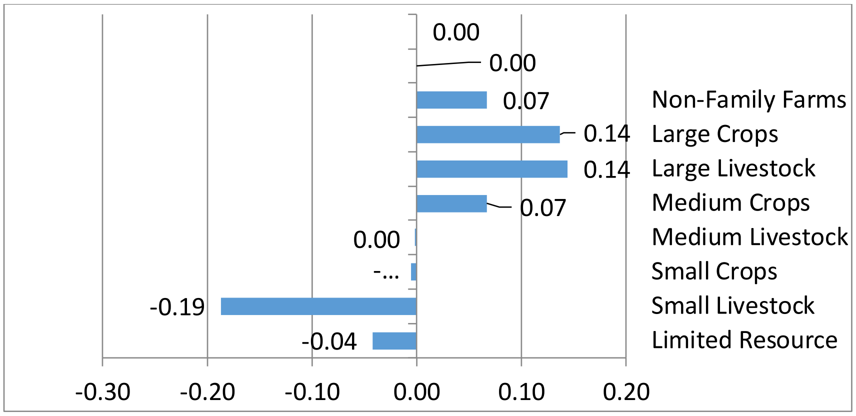
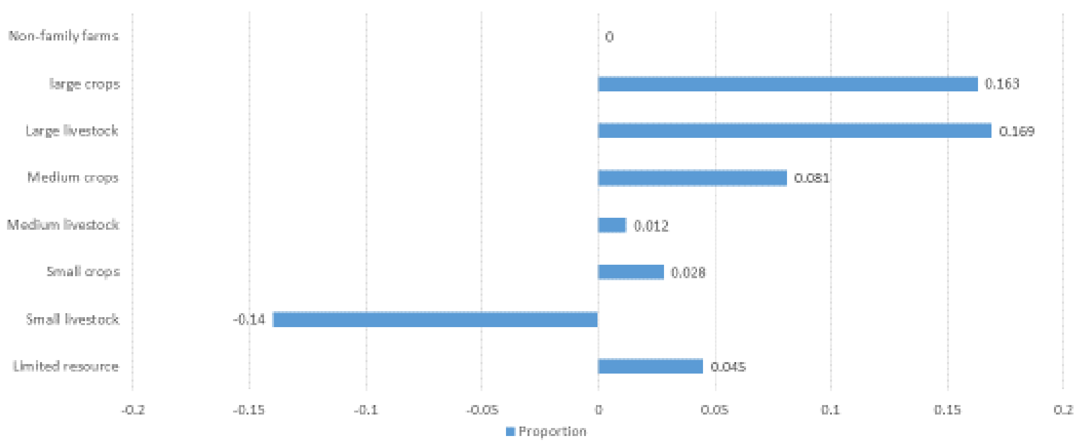


Figure 5. Household returns



Labor and Fuel Costs per acres operated

We find that labor costs per acre operated increase as farms increased in size and or became more specialized in livestock production. In the case of fuel costs per acre operated, we find that costs are higher on the more specialized livestock operations.

Figure 6. Labor expenses per acre in dollars

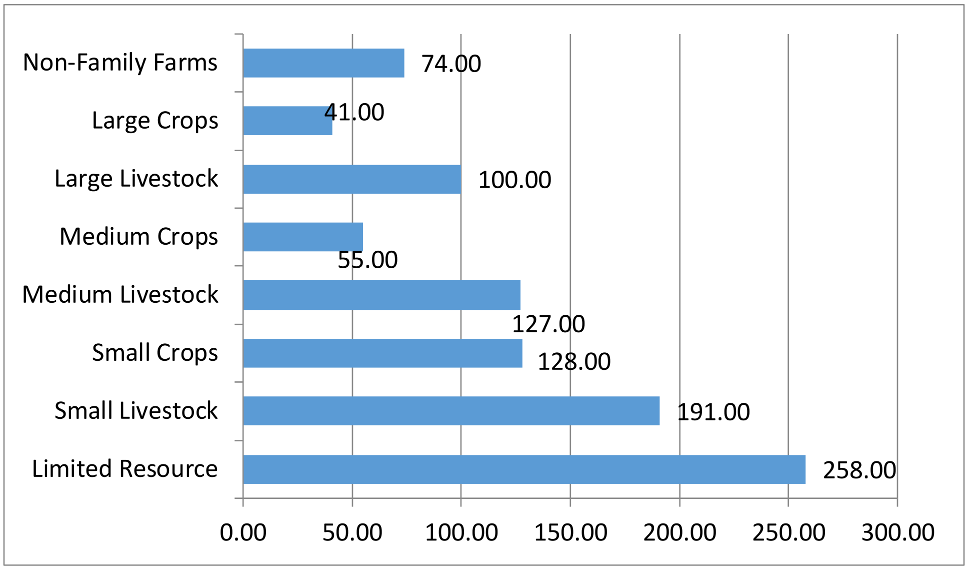
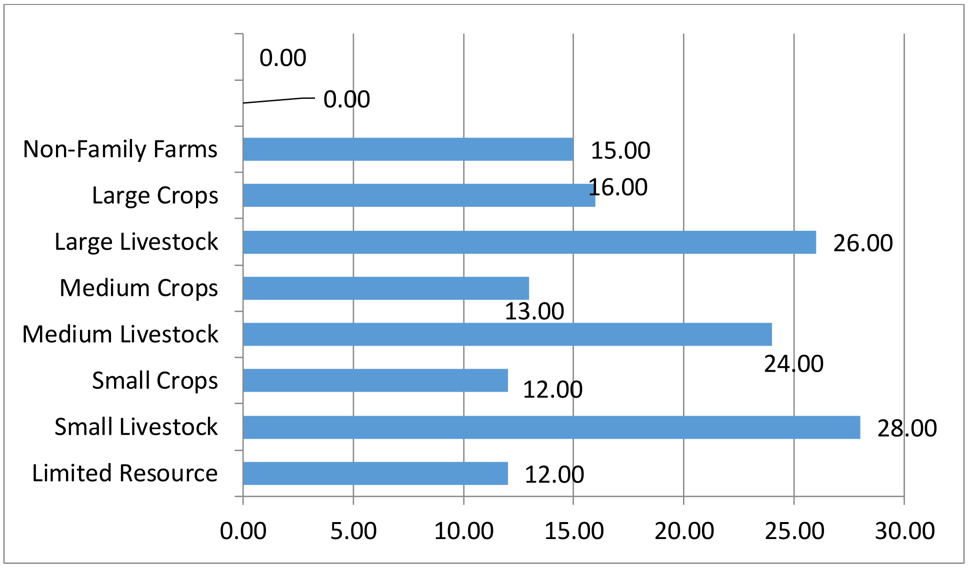


Figure 7. Fuel expenses per acre in dollars



Summary and Conclusions

This study sheds empirical light on crop/livestock production structure in the Heartland-Illinois, Indiana, Iowa, and Ohio. Based on a common analytical framework, different quantitative measures derived from an econometrically estimated transformation function are discussed. The aim is to gain insight on the relative competitiveness of the crop/livestock traditional (family) farm by focusing on alternative crop/livestock production systems at the farm level, by typology. Family farm competitiveness is not solely determined by the competitiveness of the crop/livestock production segment. We use a household production system which incorporates off-farm income into our performance measures; in the Appendix we identify the performance of traditional (family) operation compared to those that are urbanizing.

The states considered in this analysis show greater scale efficiency as livestock becomes more concentrated, as indicated by increased returns to scale with higher livestock numbers per farm, and, as size of crop operation increases. Also, we see greater scale efficiency in the small and medium crop and livestock groups due to efficiencies gained from off-farm income. Furthermore, an upward trend in farm net returns on assets with larger crop/livestock operations is observed.

However, the empirical analysis also revealed a technically efficient livestock operation does not necessarily require a larger scale. Highly efficient small scale livestock operations were found in the data analyzed. This suggests that the relevant competitive edge is still determined to a great deal by off-farm or urbanization parameters. The empirical findings for the effects of crop/livestock diversification on medium sized farms, and off-farm income impact on small and medium farms, and the impact of urbanization also point in this direction.

As shown in Table 3, the distribution of the value of production over time indicates declines in small farm shares for both livestock and crops-relatively little change in livestock and crop shares of medium sized farms and strong gains for large farms. Clearly, livestock and crop operations that survive as small and medium sized “family” or traditional farms depend on off-farm income.

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Table 1. Farm Typology Groupings

Small Family Farms (sales less than $350,000)

1. Retirement farms. Small farms whose operators report they are retired (excludes limited-resource farms operated by retired farmers).

2. Off-farm occupation farms.* Small farms whose operators report a major occupation other than farming.

3. Farming occupation/low-sales. Small farms with sales less than $150,000 whose operators report farming as their major occupation.

4. Farming occupation/moderate-sales. Small farms with sales between $100,000 and $349,999 whose operators report farming as their major occupation.

Midsize Family Farms** (sales of $350,000 to $999,999)

5. Family farms with sales between $350,000 and $999,999 whose operators report farming as their major occupation.

Large-scale Family Farms (sales $1,000,000 or more)

6. Large family farms. Sales between $1,000,000 and $4,999,999.

7. Very large family farms. Sales of $5,000,000 or more

Nonfamily Farms (no occupation or farm size criterion)

8. Nonfamily farms. Farms for which principal operator and those related to the principal operator own 50% of the farm business.

Source: Hoppe: America's Diverse Family Farms. U.S. Department of Agriculture, Economic Research Service. EIB-164. December 2016.

***** Operator spend 50 percent or more of work time

** Majority of business owned by family

Table 2 : Summary Statistics and Performance measures for Crop/Livestock Farms by Group, 2002-15 ; real 2002 dollars

Item	GROUP							
	Limited resource farms	Small Livestock VPL>$250,000*	Small Crops VPL<=$250,000	Medium Livestock VPL>$250,000	Medium Crops VPL<=$250,000	Large Livestock VPL>$250,000	Large Crops VPL<=$250,000	Non-family farms
Number of observations	3,458	4,555	**4,476**	4,144	4,171	2,656	2,680	883
Number of farms	23.8	23.0	22.4	10.8	10.5	3.2	3.6	2.6
Percent of value of production	6.6	11.5	10.8	15.9	18.1	15.3	18.0	3.9
Dairy cows per farm	0.35	13.03	4.38	39.00	2.76	81.28	0.41	8.30
Gross Sales	77,456	210,685	119,714	523,952	439,992	1,898,635	1,436,034	465,374.
Hogs per Farm	12.94	1,607.63	23.92	1,429.60	49.12	2,746.29	32.63	161.38
Animal production	13,302	808,905	22,407	745,668	27,410	1,618,953	14,9258	121,841
Livestock Prop	0.15	0.89	0.16	0.80	0.06	0.77	0.01	0.26
Earned income	48,961	22,675	17,668	17,663	23,481	24,352	47,373	0.000
Expenditures				(Dollars/harvested acre)				
Labor	257.65	190.74	128.48	126.89	55.03	100.07	40.65	73.74
Fertilizer	70.04	63.97	63.23	67.81	79.26	79.86	90.95	77.66
Fuel	11.59	27.64	11.54	23.61	13.23	25.57	15.71	15.49
Technical and Financial								
RTS	2.316	0.617	2.020	0.641	1.259	0.441	0.754	1.657
Technical Efficiency	0.927	0.931	0.926	0.930	0.921	0.912	0.912	0.923
Corn Yield	130.39	122.04	123.26	110.04	141.37	114.09	155.68	138.70
Other variables								
Average acres operated	282.8	460.5	438.3	1,071.8	977.5	2,239.6	2,079.9	1,010.2
Operator off-farm work Hrs	1,181.691	238.800	342.493	295.337	279.970	238.190	238.271	221.613
Spouse off-farm work Hrs	887.572	510.542	743.032	747.803	725.961	676.529	631.820	351.611
Proportion off-farm	0.387	0.047	0.198	0.045	0.051	0.032	0.016	0.000
Net Return on Assets	-0.042	-0.014	-0.005	0.044	0.072	0.121	0.158	0.067
Population Accessibility	155.462	110.832	143.721	101.517	133.586	115.057	149.727	146.059
Land price (quality-Adj)	3,811	3,861	3,557	4,158	4,600	5,235	5,193	4,248
Age	53.861	49.456	56.514	50.785	54.477	53.342	54.288	53.209
Education Level	2.725	2.517	2.440	2.563	2.744	2.821	2.879	2.645

All the variables measured in dollars are deflated to 2002 dollars using the indexes of prices received and paid from USDA's *Agricultural Statistics*. ERS analysis of USDA ARMS data 2002-2015. *VPL=Value of production of livestock.

Table 3: Characteristics of farms including technical efficiency and returns to scale, by typology and Livestock/Crop Farms, 2002-15 and 2002-2008 compared to 2009-2015.

Item	**Limited Resource farms**	**Small Farms: Livestock**	**Small Farms: Crops**	**Midsize Farms: Livestock**	**Midsize Farms: Crops**	**Large Farms: Livestock**	**Large Farms: Crops**	**Non-Family Farms**
					2002-2015			
Efficiency score	0.927	0.931	0.926	0.930	0.921	0.912	0.912	0.923
Returns to scale	2.316	0.617	2.020	0.641	1.259	0.441	0.754	1.657
Net return on assets	-0.042	-0.014	-0.005	0.044	0.072	0.121	0.158	0.067
Household assets return	0.045	-0.140	0.028	0.012	0.081	0.169	0.163	0
Ophours off-farm	1,181.691	238.800	342.493	295.337	279.970	238.190	238.271	221.613
Sphours off-farm	887.572	510.542	743.032	747.803	725.961	676.529	631.820	351.611
Percent of production	6.6	11.5	10.8	15.9	18.1	15.3	18.0	3.9
Sub-sample					**2002-2008**			
Ophours off-farm	1,346	245	365	274	246	183	151	366
Sphours off-farm	859	495	792	804	710	674	587	599
Percent of Production	7.2	3.2	29.5	10.2	22.6	14.2	8.8	4.2
Sub-sample					**2009-2015**			
Ophours off-farm	940	228	298	311	299	265	266	20
Sphours off-farm	928	538	650	705	735	678	646	7
Percent of Production	6.1	1.9	13.2	8.4	26.5	18.3	22.0	3.7

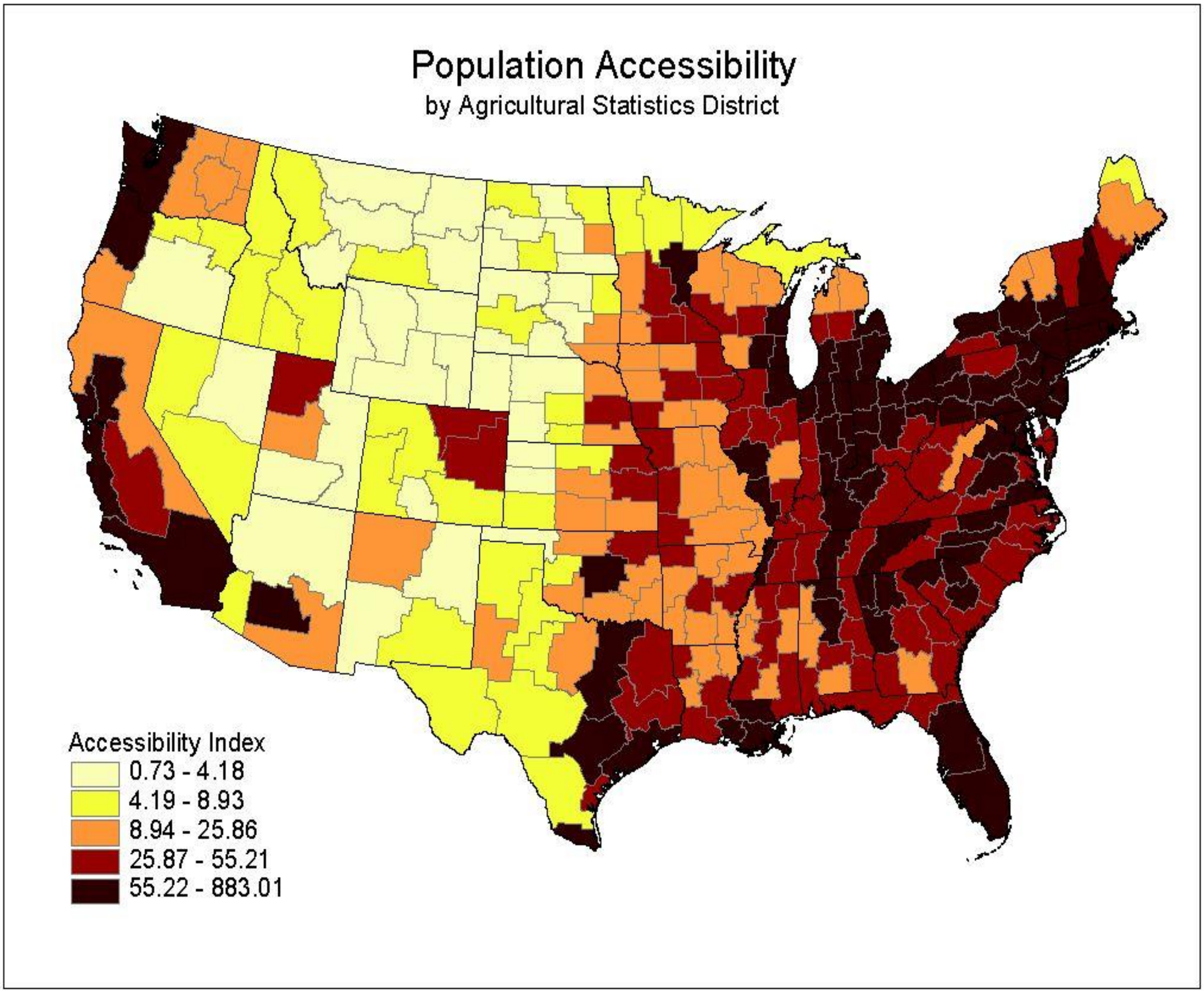
Source: ERS estimates: All the variables measured in dollars are deflated to 2002 dollars using the indexes of prices received
and paid from USDA's *Agricultural Statistics*.ERS analysis of USDA ARMS data 2002-2015.

Appendix: The Impact of Urbanization on Economic performance of Heartland Farms

Parametric results

Appendix Figure 1 categorizes farms by their population accessibility score (see Nehring et al. 2006). Observe that higher population accessibility scores connote higher impacts of urbanization (limited labor output suppliers and urban influence on land prices). Following Nehring et al. 2006 we classify farms having a population accessibility score of less than or equal to 115 being classified as rural and those with a score greater than 115 as urban. Using a transformation function analysis (with the specification described above) for the 2002-2014 ARMS data, we find that urbanization leads to a increase in scale efficiency as the population accessibility score decreases; we achieve a RTS finding of 1.66 for rural and 2.307 for urban. Both groups achieved the same technical efficiency level. The results indicate that traditional corn/soybean/livestock farms are at a competitive disadvantage in urban-influenced areas, as reflected in lower productivity, and lower returns on assets shown in Appendix Table 2. See also the DEA results below which show that rural farms are more scale efficient and technically more efficient.

Appendix Figure 2. Population Accessibility Scores by ASD 1990



Source: USDA/ERS Analysis of 1990 Census and USDA/NASS Data.

Appendix Table 1. Cost and Performance Ratios on Farms by Level of Urbanization, 2002-2014
Heartland

Item	Rural	Urban	t-statistic Urban versus Rural
Number of farms	21,345	3,562	
Percent of farms	75.0	25.0	
Percent of value of production	92.0	8.0	
Proportion corn	0.35	0.23	***
Proportion soybeans	0.21	0.23	***
Labor costs per acre ($)	82.00	231.00	**
Fuel costs per acre ($)	11.62	12.78	---
Fertilizer costs per acre ($)	56.95	61.00	***
Capital costs per acre ($)	55.81	59.92	*
Pesticide costs per acre ($)	28.78	29.07	**
Corn yield in bushels per acre	163.70	156.20	***
Soybean yield in bushels per acre	46.90	46.20	**
Cotton yield in bushels per acre	-----	----	----
RTS	1.66	2.307	
Technical efficiency	0.924	0.927	
Characteristics			
Price of land per acre	4,746.00	3,713.00	**
Acres operated	773.00	310.00	***
Prop Off-farm (percent)	5.40	33.00	***
Return on Assets (percent)	5.30	-0.01	***
Household Return (percent)	7.50	4.50	---
Operator age	54.60	55.40	---
Beef no	25.70	9.30	***
Dairy no	3.00	4.40	***
Hogs no	130.10	40.70	***
Chickens no	24.30	150.00	***

Source; ERS analysis and ARMS data 2002-2014.

Non-Parametric results

Many researchers have also used DEA techniques to estimate performance measures to satisfactorily validate the parametric input distance function approach followed in this paper that present performance measures by group (see e.g. Morrison et al. JPA 2004. Following the pseudo panel approach used in Morrison et al. (thus output and input observations on crop farms are reasonably homogeneous enabling feasible DEA solutions) the DEA approach for the ARMS data set used can a provide deterministic frontier that identifies legitimate performance measures by group. Following Färe et al. (1994) we take an input perspective as used in the input distance function presentation in this paper, that calls for modelling an input requirement set. Let *L(y)* denote this set comprised of the vector of inputs $x = (x_1,..., x_N) \in R_+^N$ used to produce outputs $y = (y_1,..., y_M) \in R_+^M$. For observations $k=1,...,K$ this input requirement set can be constructed using DEA or activity analysis as follows:

$$
\begin{aligned}
L(y \mid C, S) = \{(x_1,..., x_N) :& \\
& \sum_{k=1}^{K} z_k y_{km} \geq y_m,\ m = 1,..., M, \\
& \sum_{k=1}^{K} z_k x_{kn} \leq x_n,\ n = 1,..., N, \\
& z_k \geq 0,\ k = 1,..., K\}
\end{aligned}
$$

(1)

where the z_k variables are intensity variables used to build this technology. The above technology is characterized by constant returns to scale (C) and free disposability (S). Free disposability is represented by the inequality signs in the output and input constraints above.

The scale of technology can be modified by changing the restrictions on the intensity variables as follows:

$$z_k \geq 0 \text{ models constant returns to scale (C)},$$
$$\sum_{k=1}^{K} z_k = 1, z_k \geq 0, \text{ models variable returns to scale (V)},$$
$$\sum_{k=1}^{K} z_k \leq 1, z_k \geq 0 \quad \text{models non increasing returns to scale (N)},$$
$$k = 1,...,K$$

(2)

Technical efficiency measures the distance between a particular observation and the technology frontier. Figure 1 presents an illustration. Technology is represented by *L(y)* which is bounded by the technology frontier or efficiency frontier. There are two observations represented by points A and B. Point A is considered technically efficient, due to its location on the frontier of *L(y)*, while point B is considered technically inefficient. The inefficiency of point B can be calculated by taking the ration of OA/OB. This is the *Farrell Input-Saving Measure of Technical Efficiency* defined as

$$F_k(y, x \mid C, S) = \min\{\lambda : \lambda x \in L(y \mid C, S)\}.$$

We ran the input distance function, using 601 pseudo panel observations in the Heartland, Paul et al. 2004 and Williamson and Stutzman 2017 for a description of pseudo panels using ARMS. We find that the technical efficiency score for rural farms is 0.568 compared to 0.548 on urban farms in the Heartland, suggesting that more traditional rural farms are more technically efficient. We also find that scale efficiency is higher on rural farms compared to urban farms in the Heartland states analyzed.