Impacts of Urbanization on Costs of Production and Land Use in the Heartland, Southern Seaboard, and Prairie Gateway: A Farm-Level Analysis

The expansion of low-density nonfarm development into traditionally rural areas is affecting more and more U.S. farmland (Nehring, Barnard, Banker, and Breneman, 2006). The direct effect of such development, the conversion of rural lands to housing and other nonfarm uses, is well documented (Cho, Wu, and Boggess, 2003).

However, this direct conversion may be overshadowed by the secondary effects of "urban influence" on the active farmland that remains interspersed among nonfarm development. Recent studies suggest that such interspersion raises the cost of producing agricultural commodities (Nehring et al. ; Gardner; Lopez and Munoz; Abdalla and Kelsey; Lopez, Adelaja, and Andrews). For instance, Nehring et al. found that urban influence raises total variable costs per acre for traditional farms in the Heartland by more than 8 percent, and is consistent with a 67 percent higher price of land per acre. Policies such as government payments, farmland preservation, and environmental impacts that affect land use cannot be properly evaluated without including the urbanization component.

In addition, interspersion may be widespread. The 6.6 percent of non-Federal land categorized as developed by NRCS (Natural Resource Conservation Service) is estimated to "influence" a much larger proportion of U.S. farmland acres, perhaps as much as 17 percent (Barnard). Close to two-thirds of the 3,141 U.S. counties are classified as metropolitan or metro-adjacent (USDA/ERS 2004). The number of urban-influenced acres is so large (relative to acres directly required for urban use) that vast amounts of U.S. agricultural land will operate subject to urban influence indefinitely. Nelson, in a report for the Brookings Institute, estimates that an additional 35 million acres might need to be developed by 2030. More striking, the 17 percent of U.S. farmland that Barnard estimates is urban influenced represents 159 million acres. Even allowing for necessary commercial/industrial land, many times more acres are currently urban influenced than will be required for additional urban use within the next 30 years.

Objective

We use stochastic production frontier (SPF) procedures to estimate the impact of urban influence on the cost of production for traditional corn/soybean farms in the Heartland , high value crop and livestock farms in the South, and cash grain farms in the Plains States. We hypothesize that urban influence decreases the technical efficiency of such farms (not including greenhouses, nurseries, and turf operations). For example, the entire Heartland is not subject to widespread urban-influence, but some of its areas are. Ohio, for example, has some of the most ubiquitous, low-density urban influence in the United States (U.S. Census 2005).[1] Despite regional variations in urban influence, the Heartland has soil types, climate, and cropping patterns/rotations that are relatively homogeneous, helping us isolate the effect of urbanization.

Urban influence changes the cost, revenue, and operating structure of remaining active farms (Heimlich and Barnard 1992, 1997). Most studies find that urban influence creates opportunities for farms that adapt to the urbanizing environment, and imposes costs upon traditional farms (Berry; Lopez, Adelaja, and Andrews; Larson, Findeis, and Smith). Many farms can adjust their operations to tap into a growing and nearby market. The availability of seasonal labor may also benefit fringe-area farming. Some operations produce for niche markets, selling directly to consumers or providing “agri-tainment.” Increased farmland values often provide collateral to finance farm operating and capital expenses.

Several studies have found that corn and livestock producers are likely to bear added costs from (environmental) constraints on agricultural practices and the disappearance of input suppliers and output markets (Adelaja, Miller, and Taslim; Herriges, Secchi, and Babcock). Over time, traditional, land-extensive enterprises generally yield to enterprises that are more land intensive and more urban compatible. Livestock operations, particularly hog and dairy operations, which haul manure daily, are especially incompatible with urban-oriented neighbors due to negative externalities, including odors, insects, and water contaminants. High-value crops such as fruits and vegetables that can be sold directly to consumers often replace field crops (Lopez, Adelaja, and Andrews). Greenhouses, nurseries, and turf farms, which cater to urban markets, proliferate. The net effect of the positive opportunities and constraints is to increase the proportion of crops relative to livestock (Lockeretz 1989; 1986).

Much of our understanding of urban-influenced agriculture, however, is derived from studies like those cited above, that are generally based on county- or state-level analysis; the Heimlich and Barnard studies are exceptions since they are based on farm-level data. Few studies, excepting Nehring et al., have looked at the costs and benefits of urban influence on traditional enterprises at the farm level, and isolated the cost-increasing effects of urban nuisances and regulations from the revenue/profit increasing effects of new and larger markets brought about by urban proximity. This study updates the Nehring et al. effort for three regions using 2002-2014 ARMS data.

Methodology

A parametric production function approach is used to estimate performance measures, including RTS and TE. Following Morrison-Paul and Nehring (2005) and Morrison-Paul et al. (2004a,b), we estimate an input distance production function.

Stochastic Production Frontier Models

A parametric input distance function approach is used to estimate performance measures, including RTS and TE. The input distance function is denoted as $D^I(\boldsymbol{X},\boldsymbol{Y},\boldsymbol{R})$, where $\boldsymbol{X}$ refers to inputs, $\boldsymbol{Y}$ to outputs, and $\boldsymbol{R}$ to other farm efficiency determinants. For the analysis, three outputs developed from the ARMS for crop/livestock farms are: Y_{CORN} = value of corn production, $Y_{NONCORN}$ = value of non corn production and livestock production included in the data, and Y_{OFF} = off-farm income, which is total off-farm income less unearned income. Inputs are costs of: X_{LAB} = labor; X_{CAP} = capital; X_{MISC} = miscellaneous including feed, fertilizer, and fuel; and X_{QLND} = quality adjusted land. Thus, our analysis is whole-farm.

The input distance function represents farms' technological structure in terms of minimum inputs required to produce given output levels, as farmers typically have more short-term control over input than output decisions (Morrison-Paul et al. 2004a,b). Also, Morrison-Paul and Nehring (2005) found output-oriented models to have limitations—a less good fit—when output composition differences are important, as is the case in the crop/livestock surveys used in this study, designed to include very small crop/livestock farms along with large crop/livestock farms to get population estimates. See Morrison-Paul and Nehring (2005), and Dorfman and Koop (2005), for ARMS applications of distance functions.

To account for differences in land characteristics, state-level quality-adjusted values for the U.S. estimated in Ball et al. (2008) are multiplied by pasture plus non-pasture acres to construct a stock of land by farm. That is, the estimated state-level quality-adjusted price for each farm is multiplied by actual acres of pasture and non-pasture and a service flow computed based on a service life of 20 years and interest rate of 6%. See Nehring et al. (2006) for a fuller description. Ignoring land heterogeneity, including urbanization effects on productivity and agronomic (i.e., water holding capacity, organic matter, slope, etc., of land) and climatic information incorporating the differing cropping and pasture patterns used in crop/livestock production in the regions examined, would result in biased efficiency estimates (Ball et al. 2008; Nehring et al. 2006). Figure 1 presents one important characteristic used in the quality-adjusted land construction, soil texture, and reveals how different soil texture levels are by agricultural statistics district (ASD) in states within the Heartland, Southern Seaboard, and Prairie Gateway.

Estimating $D^I(\boldsymbol{X},\boldsymbol{Y},\boldsymbol{R})$ requires imposing linear homogeneity in input levels (Färe and Primont 1995), which is accomplished through normalization (Lovell et al. 1994); $D^I(\boldsymbol{X},\boldsymbol{Y}, \boldsymbol{R})/X_1 = D^I(\boldsymbol{X}/X_1,\boldsymbol{Y}, \boldsymbol{R}) = D^I(\boldsymbol{X^*},\boldsymbol{Y}, \boldsymbol{R})$. Approximating this function by a translog functional form to limit *a priori* restrictions on the relationships among its arguments results in:

$$\text{(1a)}\quad \ln D^I_{it}/X_{1,it} = \alpha_0 + \Sigma_m\, \alpha_m \ln X^*_{mit} + .5\, \Sigma_m \Sigma_n\, \alpha_{mn} \ln X^*_{mit} \ln X^*_{nit} + \Sigma_k\, \beta_k \ln Y_{kit}$$

$$+ .5\, \Sigma_k \Sigma_l\, \beta_{kl} \ln Y_{kit} \ln Y_{lit} + \Sigma_q\, \phi_q R_{qit} + .5\, \Sigma_q \Sigma_r\, \phi_{qr} R_{qit} R_{rit} + \Sigma_k \Sigma_m\, \gamma_{km} \ln Y_{kit} \ln X^*_{mit}$$

$$+ \Sigma_q \Sigma_m\, \gamma_{qm} \ln R_{qit} \ln X^*_{mit} + \Sigma_k \Sigma_q\, \gamma_{kq} \ln Y_{kit} \ln R_{qit} + v_{it} = TL(\boldsymbol{X^*},\boldsymbol{Y}, \boldsymbol{R}) + v_{it}, \text{ or}$$

$$\text{(1b)}\quad -\ln X_{1,it} = TL(\boldsymbol{X^*},\boldsymbol{Y}, \boldsymbol{R}) + v_{it} - \ln D^I_{it} = TL(\boldsymbol{X^*},\boldsymbol{Y}, \boldsymbol{R}) + v_{it} - u_{it},$$

where i denotes farm; t the time period; k,l the outputs; m,n the inputs; and q,r the $\boldsymbol{R}$ variables. We specify $X_1 = X_{QLND}$ as land, so the function is specified on a per-acre basis, consistent with much of the literature on farm production in terms of yields.

Distance from the frontier, $-\ln D^I_{it}$, is characterized as the technical inefficiency error $-u_{it}$. Equation (1b) was estimated as an error components model using maximum likelihood methods. The one-sided error term u_{it}, with a half-normal distribution, is a nonnegative random variable independently distributed with truncation at zero of the $N(m_{it},\sigma_u^2)$ distribution, where $m_{it}=\boldsymbol{R}_{it}\delta$, $\boldsymbol{R}_{it}$ is a vector of farm efficiency determinants (assumed to be the factors in the $\boldsymbol{R}$ vector), and δ is a vector of estimable parameters. The random (white noise) error component v_{it} is assumed to be independently and identically distributed, $N(0,\sigma_v^2)$. Estimated using SPF[1] techniques, technical efficiency (TE) is characterized assuming a radial contraction of inputs to the frontier (constant input composition).

Scale economies are calculated as the combined contribution of the M outputs Y_m, or the scale elasticity $SE = -\varepsilon_{DI,Y} = -\Sigma_m \partial \ln D^I(\boldsymbol{X},\boldsymbol{Y},\boldsymbol{R})/\partial \ln Y_m = \varepsilon_{X1,Y}$. That is, the sum of the input elasticities, $\Sigma_m \partial \ln X_1/\partial \ln Y_m$, indicates the overall input-output relationship, and thus returns to scale (RTS). The extent of scale economies is thus implied by the shortfall of SE from 1; if SE<1, inputs do not increase proportionately with output levels, implying increasing RTS. Previous studies on corn and on dairy farm efficiency using ARMS have found significant economies of size (Morrison et al. 2005, Tauer and Mishra 2006; Mosheim and Lovell 2009; Mayen et al. 2010).

Finally, TE "scores" are estimated as $TE = \exp(-u_{it})$. Impacts of changes in R_q on TE can also be measured by the corresponding δ coefficient in the inefficiency specification for $-u_{it}$. σ^2. It is assumed that the inefficiency effects are independently distributed and u_{it} arise by a truncated (at zero) half-normal distribution with mean μ_{it}, and variance σ_u^2.

Input endogeneity has been a concern in the estimation of input distance functions; if found, biased estimates result. Some studies have used instrumental variables to correct the problem, while others have argued either that (1) it was not problematic in their studies because random disturbances in production processes resulted in proportional changes in the use of all inputs (Coelli and Perelman 2000, Rodriguez-Alvarez 2007) or (2) no good instrumental variables existed, thus endogeneity was

1 We used STATA Version 12 commands for the SPF estimation.

not accounted for (Fleming and Lien 2010). We estimate instruments for the 2 potential drivers of inefficiency, operator hours worked off-farm (ophours) and spouse hours worked off-farm (sphours)2.

The Hausman test was used to test for endogeneity. Since endogeneity was found, the predicted values for ophours and sphours are used as instruments in the SPF[3].

USDA's Annual Surveys and Data Construction.

Data

We use U.S. farm-level crop/livestock data from the 2002 to 2014 ARMS USDA surveys related to the value of output and cost of production in our analysis. The states covered are Georgia, North Carolina, and South Carolina in the Southern Seaboard; Illinois, Indiana, Iowa, and Ohio in the Heartland; and Nebraska, Oklahoma, and Texas in the Prairie Gateway. The data set consists of 34,595 observations of farms growing crops and including livestock operations in the Heartland, 27,243 crop/livestock operations in the Southern Seaboard, and 30,008 crop/livestock operations in the Prairie Gateway. The list and area frame components are incorporated using a system of weights. Inferences for the states and regions must account for the survey design by using weighted observations. The farm-level data is used in an innovative way. We define three outputs: Gross value of sales from non-corn output (including livestock), corn output, and off-farm income, and four inputs: labor, miscellaneous, capital, and a quality adjusted land input. We use regression techniques

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2 For the major crop/livestock regions analyzed in this study average annual operator hours worked off-farm during 2002-2014 range from about 500 hours in the Prairie Gateway to close to 700 hours in the Southern Seaboard. And, for the regions analyzed in this study average annual spouse hours worked off-farm during 2002-2014 range from 750 in the Heartland to less than 600 in the Southern Seaboard.

3 The problem of endogeneity occurs when the independent variable is correlated with the error term in a regression model. In the case of the regions analyzed in this manuscript, off-farm use of labor is a major source of income on many farms.

Hence, it is desirable to use instrumental variables in order to predict operator and spousal labor off-farm from information that influences such decisions such as age and education (see Huffman et al 1997 and Huffman et al 2004 for an understanding of how instruments are used to ascertain how off-farm work decisions influence on farm labor use). More precisely, we employ instruments to predict the level of operator or spousal hours off-farm, variables that do not directly influence production but do influence the labor use off-farm. For the operator we consider population accessibility, household assets, crop production, livestock production, household wellbeing, and animal units as important drivers of off-farm employment. For the spouse we that allow us to relate several outputs to several inputs in a single equation to develop measures of technical (best practice production techniques) and scale efficiency scores by farm. We use stochastic production frontier (SPF) measurement to econometrically estimate an input distance function frontier. We will test for and correct for inputs that are endogenous to the production process.

Urban-Influence Variables

Our two urban-influence variables, described in Barnard, Wiebe, and Breneman, are a continuous index and a categorical variable created from the continuous index. The index was created from an analysis of block-level group population data from the 1990 Census of Population (USDC/BL). Using statistical smoothing techniques within a Geographic Information System (GIS) framework, population was estimated for each cell in a 5-km grid laid out across the total U.S. land area. An index number was calculated for each cell using a GIS function based on the concept of a "gravity" model of urban development. In our study, urban influence at a single grid cell location is defined as follows: $U_{ij} = \{P_j / D_{ij}\}$ where U_{ij} is the computed index number representing the influence on cell i of the population located in cell j, P_j is the population of cell j, and D_{ij} is the distance from cell i to cell j.[4] In order to assess the effect on cell i of proximity to population in multiple nearby cells, the index is aggregated across n possible locations (cells). In an aggregate form, the index used in this study for each cell is given by: $UI_i = \sum_{j=1}^{n} \{P_j / D_{ij}\}$ where the index j represents grid cells within a 50 mile radius of cell i.

The continuous index increases as population increases, (since population is in the numerator) and/or as distance to the population decreases (since distance is in the denominator). The index number assigned for each county is the value of the index as measured at the geographic center of

consider population accessibility, household assets, crop production, and the adjusted wage as important drivers of off-farm employment. We include the

the county (centroid). Computed values of UI_i used in this analysis range from less that 10 to greater than 6,000, with the majority ranging from 20 to 700. The urban-influence index is modeled as an inefficiency effect in equation (2), and is used as a characteristic in the hedonic specification from which the quality-adjusted price of land is estimated.

The continuous urban-influence index, however, does not identify which counties are rural and which are urban influenced. To do that and to create the categorical variable, we set thresholds for the continuous variable based on the level of the urban-influence index in "totally rural" census tracts (which were previously defined by Cromartie). "Totally rural" means that the census tract does not contain any part of a town of 2,500 or more residents and that the primary commuting pattern was to sites within the census tract. Any parcel not satisfying these conditions was considered urban influenced. Those cells classified as urban influenced were subdivided into three categories labeled near rural, near urban, and urban, each representing an increasing level of urban influence. More specifically, we defined counties as rural if UI_i <=115, near rural if 115< UI_i <=155, near urban if 155< UI_i <=236, and urban if UI_i >236.

Figure 2 presents the spatial distribution of the rural and urban-influenced categories by ASD. Regional variations in the level of urban-influence are important and tend to be highest in the eastern United States and West Coast.

Summary of Data Construction

As shown in tables 1, 2 and 3 urban-influenced farms are particularly important in the Heartland and Southern Seaboard**,** comprising 50 percent of all farms in the Heartland and Southern Seaboard, and accounting for about 40 percent of production in the Heartland and almost 60

predicated values of these two variables in the inefficiency effects reported in Tables 4, 5 and 6.

percent of farms an almost half of production in the Southern Seaboard. In contrast, urban farms account for only 23 percent of farms and less than 10 percent of production in the Prairie Gateway. In all three regions rural farms tend to exhibit an advantage in crop yields. In the Heartland urban-influenced farms average about 283 acres, significantly less than rural farms, which average close to 426 acres. Similarly, in the Southern Seaboard urban-influenced farms average about 140 acres, compared to an average close to 272 acres on rural farms. And, in the Prairie Gateway urban farms about one-third the size of rural farms, about 250 acres compared to 786 acres. We consider this an endogenous effect of urban influence. Accordingly, assessment of the impacts of urban influence on technical efficiency must take farm size into account. Urban-influenced farms also show higher total variable costs, including higher labor, fuel, fertilizer, seed, pesticides, and machinery costs than do rural farms—all costs measured in real terms based on 1998 prices. Off-farm income is significantly higher on urban-influenced farms as expected. Age does not tend to differ among urban-influenced and rural farms.

The Empirical Results

Stochastic frontier

The parameter estimates for regional crop/livestock household models are reported in Tables 4,5, and 6. Although most of the parameter estimates of the primal are not directly interpretable due to the flexible functional form (the elasticity measures are combinations of various parameters and data) the estimates of the acres and year dummies are directly interpretable. The acre dummy is defined as one if farms have acres operated of greater than 1000 acres and zero otherwise. The year dummy is defined as one if year is greater or equal to 2008 and zero otherwise. Hence, the input model results for the acre dummy (ACREDUM), suggest a (statistically significant) increase in productivity for farms operating at least 1000 acres in the Prairie Gateway only. And the dummies for the year break of 2008 or later (YEARDUM) suggests a statistically significant increase in productivity in later years in all three regions, implying robust yield increases over time. Also, the variables in the technical inefficiency effects are directly interpretable and are discussed below under farm employment.

Off-farm Employment

As discussed earlier, the importance of off-farm income to economic well-being of all U.S. farmers is widely acknowledged, 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 this section we examine the drivers of off-farm hours worked off-farm by operator and spouse[4]. As noted above the variables in the technical inefficiency effects are directly interpretable. Notably, we find that higher number of operator hours in off-farm work decrease technical efficiency in the Heartland, suggesting that this activity reduces the time spent on making effective management decisions in the farm operation. Also we find a significant negative impact on technical efficiency as spouse hours (about 80 percent of the total) worked off-farm increase in the Heartland and Southern Seaboard. And, the positive and statistically significant coefficient on year suggest that technical efficiency has increased over time in all three regions.

Empirical Results

Comparison of Rural and Urban-Influenced Costs of Production

4 The instrumental variable results indicate that for operator hours, household assets (-) and household wellbeing (+) are important drivers of off-farm employment. The time dummies indicate significant declines in 2008 and 2010. The instrumental variable results indicate that for the spouse hours, house hold assets (-) and the adjusted wage (+) are important drivers of off-farm employment. The time dummies indicate significant increases in 2005, 2008 and 2010. These results are available on request.

Below we compare cost of production on rural and urban-influenced farms both by degree of urbanization—rural, medium, and high. We can learn more about the specific costs due to urban influence and the associated farm and operator characteristics by linking individual input characteristics to the degree of urban influence.

To examine costs relative to degree of urban influence we compare costs and performance on rural farms (UI_i <115), to medium-urban influenced farms (115<= UI_i <236), and high-influenced farms (UI_i >236). As shown in tables 7, 8, and 9 land prices, as one would expect, generally follow a clear pattern as our index of urbanization increases, jumping from $2,698 per acre on rural farms in the Southern Seaboard to $3,862 on medium urban influenced farms, and jumping again to $5,649 per acre on high-urban influenced farms. We see a similar pattern in the Prairie Gateway. Only the Heartland is an exception, likely because of generally robust corn prices during the period analyzed, with rural farms showing the same land value as medium urban farms but falling 15 percent below the land values on high-influence farms. A t-test of equal means for the rural and high-medium urban-influenced categories is conducted as shown in tables 7, 8 and 9. The comparisons in these tables generally show lower technical efficiency as urbanization increases and lower scale efficiency. For example in the Heartland, medium and high urban farms exhibit significantly lower technical efficiency than rural farms. Variable costs per acre generally remain high or continue to increase. And, it is noteworthy that returns on assets tend to be lower on medium-high urban influence farms compared to rural farms in all three regions.

Summary and Conclusions

Popular press and numerous studies relying on aggregate data suggest that the interspersion of agricultural and urban-related activities raises the cost of producing agricultural commodities in urban-influenced areas. Examining USDA farm-level survey data on costs, we find that urban influence significantly raised variable costs per acre for traditional farms in the central Heartland, Southern Seaboard and Prairie Gateway 2002-2014. Urban-influenced farms are also less technically efficient than rural farms in all three regions.

Using SPF analysis, we find that urbanization leads to a decrease in technical efficiency. For 2002-2014, an increase in urban influence leads to significantly lower technical efficiency for traditional farms. Traditional corn/soybean/livestock farms are at a competitive disadvantage in urban-influenced areas, as reflected in lower technical efficiency, lower productivity, and lower returns on assets.

Future research, examining high performance urban-influence farms (farms with technical efficiency scores above the median for all urban influenced farms), as in the Nehring et al. presentation, may provide information on how such farms have controlled costs. Nehring et al., for example found that such high performance urban farms in the Heartland tend to de-emphasize livestock activities, do not rely extensively on off-farm income, and are larger and more grain-oriented than less successful urban-influenced farms.

The potential impact of urbanization on rural agriculture is not of minor importance. The urban-influenced farms that we analyzed represent more than 50 percent of all farms in the Heartland, about 60 percent in the Southern Seaboard, and more than 20 percent in the Prairie Gateway; and about 40 percent of the value of production in the Heartland, almost 50 percent of production in the Southern Seaboard, but only about 10 percent of production in the Prairie Gateway during 2002-2014. Current Census data indicate clusters of fast growth rural counties sprinkled throughout the Heartland suggesting that urban influence on agriculture will grow in the future, particularly in the northern Heartland. To properly measure farm-level economic activity given this phenomenon requires an analysis of agricultural production that recognizes the role of nonagricultural demand for land and realizes that farms face differing levels of urban pressure.

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

Item	Rural	Urban	t-statistic Urban versus Rural[a]
Number of farms	18,032	16,563	
Percent of farms	48.7	51.3	
Percent of value of production	61.0	39.0	
Proportion corn	0.35	0.23	***
Proportion soybeans	0.21	0.23	***
Labor costs per acre ($)	196.83	416.24	**
Fuel costs per acre ($)	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	-----	----	----
Characteristics			
Price of land per acre	4,294.20	5,231.00	**
Acres operated	425.60	283.00	***
Prop Off-farm (percent)	16.20	24.60	***
Return on Assets (percent)	5.30	4.00	***
Household Return (percent)	7.90	7.80	---
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	***

Note: Three asterisks indicate significance at the 1% level (t=2.576), two indicate significance at the 5% level (t=1.96), and one indicates significance at the 10% level (t.=1.65).
Source: Model results and USDA data 2002-2014 ARMS.
a.The t-statistics are based on weighting techniques described in Dubman.

Table 2. Cost and Performance Ratios on Farms by Level of Urbanization, 2002-2014 Southern Seaboard

Item	Rural	Urban	t-statistic Urban versus Rural[a]
Number of farms	13,220	14,023	
Percent of farms	40.7	59.3	
Percent of value of production	52.9	47.1	
Proportion corn	0.04	0.02	***
Proportion soybeans	0.05	0.05	***
Labor costs per acre ($)	398.36	1,186.83	***
Fuel costs per acre ($)	15.66	17.56	---
Fertilizer costs per acre ($)	53.08	41.61	***
Capital costs per acre ($)	44.33	54.60	**
Pesticide costs per acre ($)	61.32	37.82	***
Corn yield in bushels per acre	117.40	98.30	***
Soybean yield in bushels per acre	31.00	29.00	**
Cotton yield in bushels per acre	814.50	760.30	***
Characteristics			
Price of land per acre	2,698.20	4,872.60	***
Acres operated	272.30	140.60	***
Prop Off-farm (percent)	28.10	50.90	***
Return on Assets (percent)	4.20	2.10	***
Household Return (percent)	7.50	7.60	---
Operator age	58.80	58.80	---
Beef no	25.70	9.40	***
Dairy no	3.00	4.60	***
Hogs no	130.10	41.20	***
Chickens no	24.30	175.80	***

Note: Three asterisks indicate significance at the 1% level (t=2.576), two indicate significance at the 5% level (t=1.96), and one indicates significance at the 10% level (t.=1.65).
Source: Model results and USDA data 2002-2014 ARMS.
a.The t-statistics are based on weighting techniques described in Dubman.

Table 3. Cost and Performance Ratios on Farms by Level of Urbanization, 2002-2014 Prairie Gateway

Item	Rural	Urban	t-statistic Urban versus Rural[a]
Number of farms	25,792	5,116	
Percent of farms	77.3	22.7	
Percent of value of production	91.3	8.7	
Proportion corn	0.08	0.03	***
Proportion soybeans	0.04	0.01	***
Labor costs per acre ($)	185.87	1,207.76	***
Fuel costs per acre ($)	4.88	6.76	---
Fertilizer costs per acre ($)	11.01	13.86	**
Capital costs per acre ($)	55.81	57.90	*
Pesticide costs per acre ($)	16.86	24.66	***
Corn yield in bushels per acre	154.30	97.65	***
Soybean yield in bushels per acre	46.10	38.65	***
Cotton yield in bushels per acre	632.20	622.30	---
Characteristics			
Price of land per acre	1,219.15	2,521.00	***
Acres operated	786.00	254.90	***
Prop Off-farm (percent)	36.30	67.50	***
Return on Assets (percent)	3.30	1.50	***
Household Return (percent)	8.10	9.70	***
Operator age	58.20	57.80	---
Beef no	61.20	25.40	***
Dairy no	2.20	0.40	***
Hogs no	10.50	0.50	**
Chickens no	484.80	31.50	***

Note: Three asterisks indicate significance at the 1% level (t=2.576), two indicate significance at the 5% level (t=1.96), and one indicates significance at the 10% level (t.=1.65).
Source: Model results and USDA data 2002-2014 ARMS.
a.The t-statistics are based on weighting techniques described in Dubman.

Figure 1. Texture Index By ASD

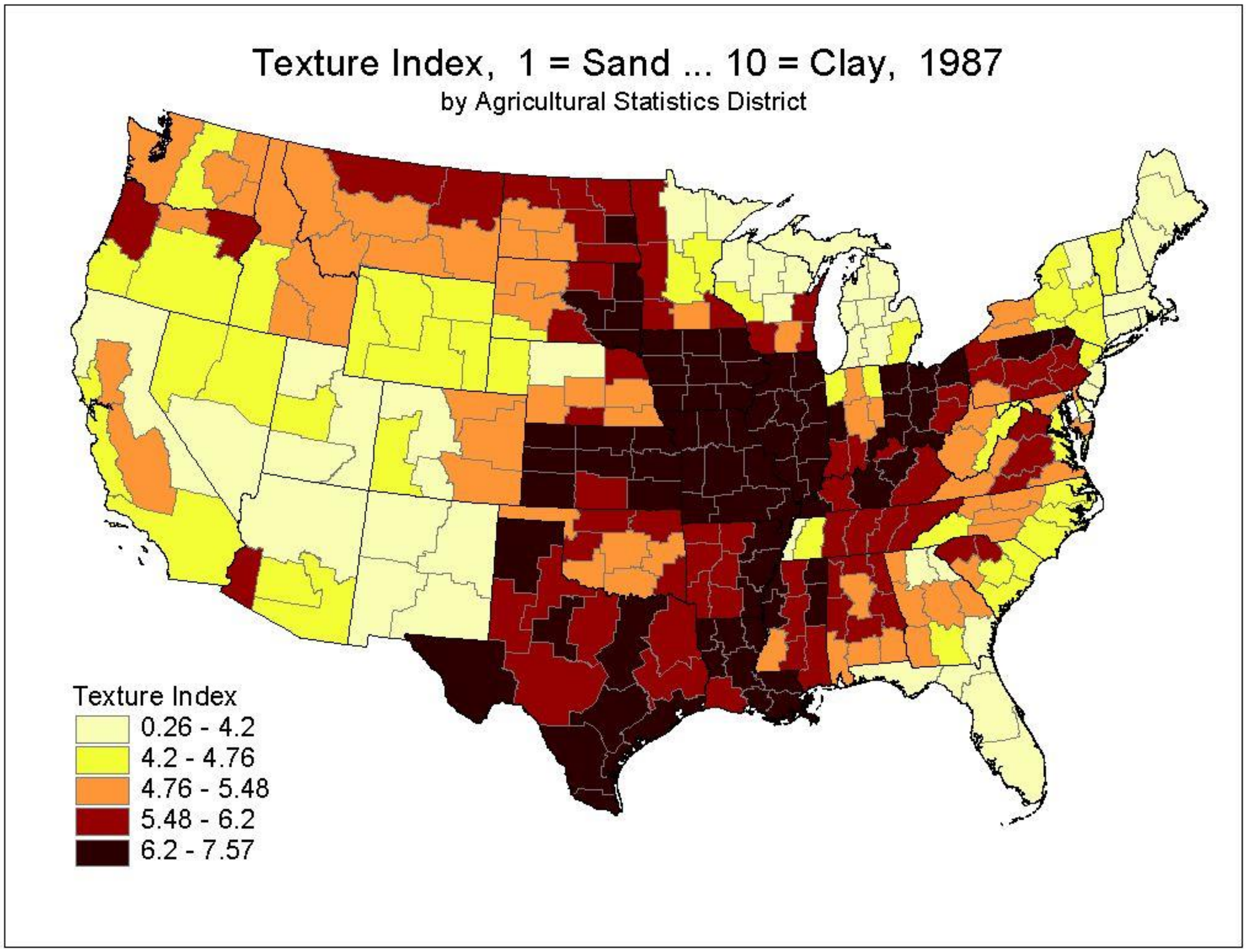

Figure 2. Population Accessibility Scores by ASD 1990

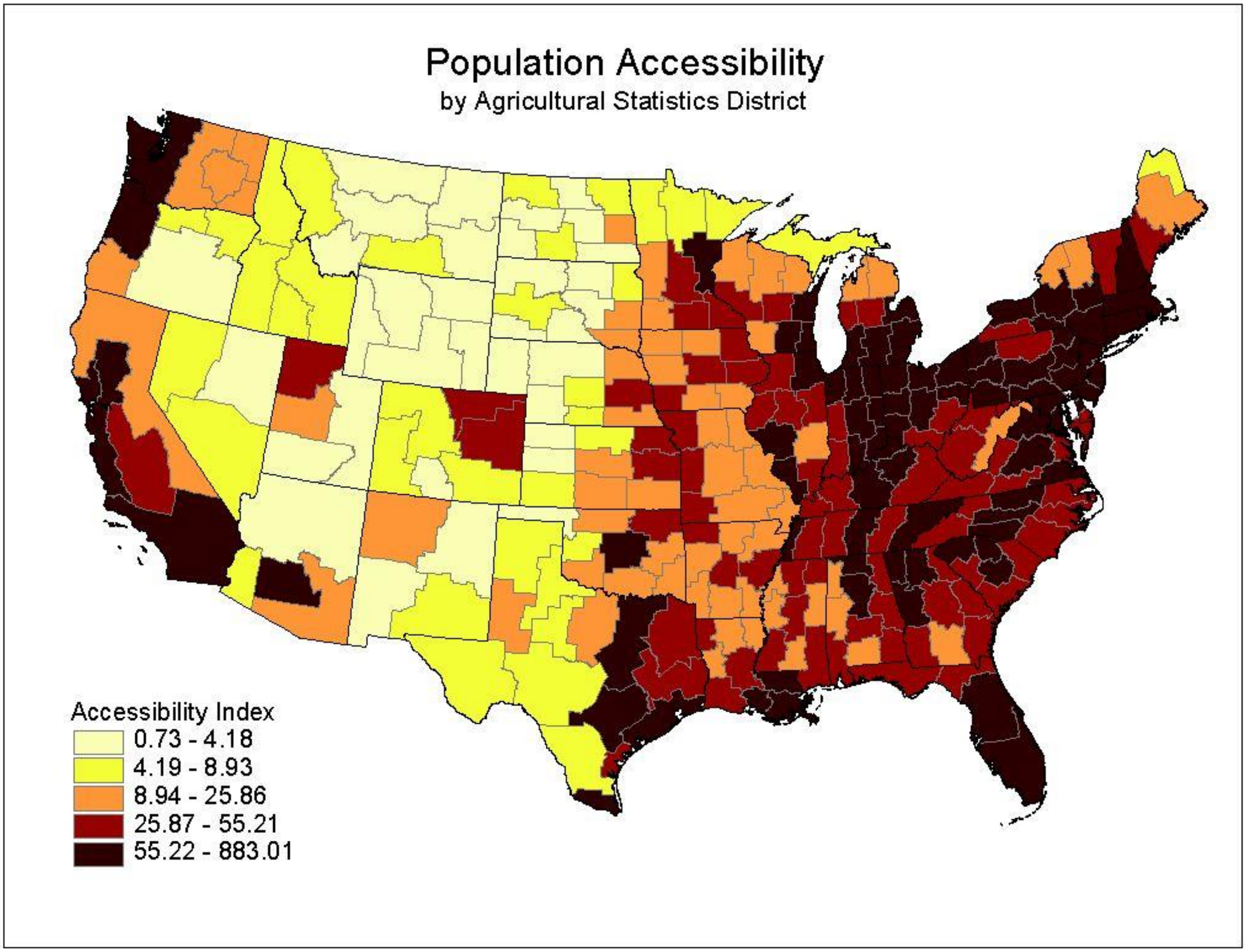

Table 4. Input Distance Function Parameter Estimates, 2002-2014 Heartland.

Variable	Parameter t-test	Variable	Parameter t-test
α_0	7.071 (11.11)***	$\alpha_{XLAB,XLAB}$	-0.006 (3.71)***
α_{XLAB}	-0.123 (-17.85)***	$\alpha_{XMISC,XMISC}$	-0.043(-19.86)***
α_{XMISC}	-0.250 (-25.67)***	$\alpha_{XCAP,XCAP}$	-0.003 (-2.36)**
α_{XCAP}	-0.074 (-13.94)**	$\alpha_{XLAB,XMISC}$	0.011 (2.84)**
$\beta_{YNONCORN}$	-0.051 (-4.21)***	$\alpha_{XLAB,XCAP}$	0.002 (0.75)
β_{YCORN}	-0.412 (-27.04)***	$\alpha_{XMISC,XCAP}$	-0.003 (-1.30)
β_{YOFF}	-0.102 (-4.91)***	$\alpha_{XACRESDUM}$	-0.019 (-0.83)
$\beta_{YNCORN,YNC}$	0.016 (19.67)***	$\alpha_{XYEARDUM}$	0.297 (14.78)***
$\beta_{YCORN,YCORN}$	0.045 (45.92)***	$\delta_{INEFF\ EFFECTS}$	1.059 (0.05)***
$\beta_{YOFF,YOFF}$	0.009 (7.04)**	δ_{URBAN}	0.001 (4.84)***
$\beta_{YNCORN,YCOR}$	-0.007 (-7.50)***	$\delta_{OPLABOR}$	0.0005 (2.17)**
$\beta_{YNCORN,YOFF}$	-0.003 (-0.63)	$\delta_{SPLABOR}$	0.0003 (2.96)**
$\beta_{YCORN,YOFF}$	-0.002 (-2.00)*	δ_{OPAGE}	-0.009 (-2.65)
		δ_{YEAR}	0.165 (6.55)***
		$\delta\_{v}\_$	0.589
		Pseudo-loglikelihood	-3,753,635.6
		Eff	0.728
		RTS	0.542

Notes: ***significance at the 1% level (t=2.977), **significance at the 5% level (t=2.145), and *significance at the 10% level (t=1.761). Source: USDA, National Agricultural Statistics Service and Economic Research Service Agricultural and Resource Management Surveys (2002-2014). The t-statistics are based on 34,595 observations for the sample derived from 4 states: Illinois, Indiana , Iowa, and Ohio. The coefficient for δ_{v} does not have a t-distribution and is reported with a 95 percent confidence interval in STATA.

Table 5. Input Distance Function Parameter Estimates, 2002-2014 Southern Seaboard.

Variable	Parameter t-test	Variable	Parameter t-test
α_0	9.865 (56.17)***	$\alpha_{XLAB,XLAB}$	-0.002 (-0.89)
α_{XLAB}	-0.270 (-19.37)***	$\alpha_{XMISC,XMISC}$	-0.020(-10.21)***
α_{XMISC}	-0.086 (-12.18)***	$\alpha_{XCAP,XCAP}$	-0.002 (-0.95)
α_{XCAP}	-0.074 (-13.94)**	$\alpha_{XLAB,XMISC}$	-0.006 (-1.53)
$\beta_{YNONCORN}$	0.067 (2.74)**	$\alpha_{XLAB,XCAP}$	0.004 (1.45)
β_{YCORN}	-0.293 (-12.11)***	$\alpha_{XMISC,XCAP}$	-0.011 (-3.60)***
β_{YOFF}	-0.198 (-4.74)***	$\alpha_{XACRESDUM}$	0.030 (0.79)
$\beta_{YNCORN,YNC}$	0.005 (2.25)**	$\alpha_{XYEARDUM}$	0.968 (18.98)***
$\beta_{YCORN,YCORN}$	0.036 (32.51)***	$\delta_{INEFF\ EFFECTS}$	-0.611 (-1.42)
$\beta_{YOFF,YOFF}$	0.017 (6.25)**	δ_{URBAN}	0.001 (2.63)**
$\beta_{YNCORN,YCOR}$	-0.006 (-3.79)***	$\delta_{OPLABOR}$	-0.0002 (-1.50)
$\beta_{YNCORN,YOFF}$	-0.001 (-1.49)	$\delta_{SPLABOR}$	0.0008 (0.57)
$\beta_{YCORN,YOFF}$	-0.001 (-0.43)	δ_{OPAGE}	-0.011 (-2.49)
		δ_{YEAR}	0.077 (2.52)**
		$\delta\_{v}\_$	0.613
		Pseudo-loglikelihood	-1,705,706.8
		Eff	0.610
		RTS	0.322

Notes: ***significance at the 1% level (t=2.977), **significance at the 5% level (t=2.145), and *significance at the 10% level (t=1.761). Source: USDA, National Agricultural Statistics Service and Economic Research Service Agricultural and Resource Management Surveys (2002-2014). The t-statistics are based on 27,243 observations for the sample derived from 4 states: Georgia, North Carolina, and South Carolina. The coefficient for δ_{v} does not have a t-distribution and is reported with a 95 percent confidence interval in STATA.

Table 6. Input Distance Function Parameter Estimates, 2002-2014 Prairie Gateway.

Variable	Parameter t-test	Variable	Parameter t-test
α_0	9.650 (93.32)***	$\alpha_{XLAB,XLAB}$	0.0001 (0.07)
α_{XLAB}	-0.143 (-17.41)***	$\alpha_{XMISC,XMISC}$	-0.039(-16.32)***
α_{XMISC}	-0.282 (-28.92)***	$\alpha_{XCAP,XCAP}$	-0.003 (-2.36)**
α_{XCAP}	-0.079 (-13.29)**	$\alpha_{XLAB,XMISC}$	-0.001 (-0.91)
$\beta_{YNONCORN}$	0.105 (8.02)***	$\alpha_{XLAB,XCAP}$	-0.005 (-2.02)*
β_{YCORN}	-0.341 (-22.58)***	$\alpha_{XMISC,XCAP}$	-0.003 (-0.99)
β_{YOFF}	-0.134 (-6.35)***	$\alpha_{XACRESDUM}$	0.066 (2.34)**
$\beta_{YNCORN,YNC}$	0.008 (8.27)***	$\alpha_{XYEARDUM}$	1.048 (34.34)***
$\beta_{YCORN,YCORN}$	0.042 (43.66)***	$\delta_{INEFF\ EFFECTS}$	-0.954(-18.75)***
$\beta_{YOFF,YOFF}$	0.013 (8.34)**	δ_{URBAN}	0.011 (9.75)***
$\beta_{YNCORN,YCOR}$	-0.015 (-19.12)***	$\delta_{OPLABOR}$	-0.0001 (-0.68)
$\beta_{YNCORN,YOFF}$	-0.001 (-2.89)**	$\delta_{SPLABOR}$	0.005 (2.83)**
$\beta_{YCORN,YOFF}$	-0.001 (-1.28)	δ_{OPAGE}	-0.007 (-2.70)
		δ_{YEAR}	0.131 (7.63)***
		$\delta\_{v}\_$	0.621
		Pseudo-loglikelihood	-5,313,252.5
		Eff	0.598
		RTS	0.418

Notes: ***significance at the 1% level (t=2.977), **significance at the 5% level (t=2.145), and *significance at the 10% level (t=1.761). Source: USDA, National Agricultural Statistics Service and Economic Research Service Agricultural and Resource Management Surveys (2002-2014). The t-statistics are based on 30,008 observations for the sample derived from 3 states: Texas, Oklahoma, and Nebraska. The coefficient for δ_{v} does not have a t-distribution and is reported with a 95 percent confidence interval in STATA.

[1]Continuing population growth in more than 10 percent of the rural Heartland counties since 2000 and projections of strong long term population growth in the northern Heartland suggests that urban influence on agriculture will increase in the future.

[2] In Shi, Phipps, and Colyer and in Hardie Narayan, and Gardner, distance is accounted for using D^2. In our analysis we used D, rather than D^2, based on information in Song that the reciprocal of

distance, the most commonly used weight in gravity-type measures, is statistically equivalent to any of eight other measures.

Table 7. Cost and Performance Ratios on Farms by Level of Urbanization, 2002-2014 Heartland

Item	Rural	Medium	High	t-statistic Medium versus Rural[a]	t-statistic High versus Rural[a]
Number of farms	18,032	10,869	5,694		
Percent of farms	48.7	33.6	17.7		
Percent of value of production	61.0	16.3	13.5		
Proportion corn	0.35	0.22	0.24	***	***
Proportion soybeans	0.21	0.23	0.22	***	***
Efficiency Score	0.74	0.73	0.70	***	***
Returns to Scale	0.59	0.50	0.49	***	***
Labor costs per acre ($)	196.83	365.96	518.95	**	**
Fuel costs per acre ($)	11.62	11.96	14.48	---	***
Fertilizer costs per acre ($)	56.95	59.81	63.46	---	***
Capital costs per acre ($)	55.81	57.90	64.07	---	***
Pesticide costs per acre ($)	28.78	29.07	29.57	---	---
Corn yield in bushels per acre	163.70	156.10	156.20	***	***
Soybean yield in bushels per acre	46.90	45.90	46.70	**	---
Cotton yield in bushels per acre	-----	----	----	---	---
Characteristics					
Price of land per acre	4,294.20	4,231.00	5,169.60	----	***
Acres operated	425.60	290.90	267.90	***	***
Prop Off-farm (percent)	16.20	23.50	26.50	***	***
Return on Assets (percent)	5.30	4.10	4.00	**	**
Household Return (percent)	7.90	7.70	7.90	----	---
Operator age	54.60	55.30	55.60	----	---
Beef no	25.70	10.40	7.30	***	***
Dairy no	3.00	4.20	4.80	***	***
Hogs no	130.10	44.20	34.20	***	***
Chickens no	24.30	115.80	214.90	***	***

Note: Three asterisks indicate significance at the 1% level (t=2.576), two indicate significance at the 5% level (t=1.96), and one indicates significance at the 10% level (t.=1.65).
Source: Model results and USDA data 2002-2014 ARMS.
a.The t-statistics are based on weighting techniques described in Dubman.

Table 8. Cost and Performance Ratios on Farms by Level of Urbanization, 2002-2014 Southern Seaboard

Item	Rural	Medium	High	t-statistic Medium versus Rural[a]	t-statistic High versus Rural[a]
Number of farms	13,220	9,655	4,368		
Percent of farms	40.7	36.5	22.8		
Percent of value of production	52.9	36.5	10.6		
Proportion corn	0.04	0.02	0.01	***	***
Proportion soybeans	0.05	0.05	0.02	***	***
Efficiency Score	0.62	0.61	0.58	**	**
Returns to Scale	0.34	0.32	0.30	*	*
Labor costs per acre ($)	398.36	1,066.82	1,206.19	***	**
Fuel costs per acre ($)	15.66	20.56	15.16	***	---
Fertilizer costs per acre ($)	53.08	41.61	25.87	***	***
Capital costs per acre ($)	44.33	58.60	48.91	**	*
Pesticide costs per acre ($)	61.32	47.82	29.70	***	***
Corn yield in bushels per acre	117.40	92.30	103.20	***	***
Soybean yield in bushels per acre	31.00	27.00	30.50	---	---
Cotton yield in bushels per acre	814.50	740.30	806.90	***	---
Characteristics					
Price of land per acre	2,698.20	3,862.20	5,649.10	***	***
Acres operated	272.30	150.60	111.80	***	***
Prop Off-farm (percent)	28.10	40.90	58.40	***	***
Return on Assets (percent)	4.20	3.10	1.00	***	***
Household Return (percent)	7.50	7.60	7.10	---	---
Off-farm income	74.47	118.40	127.41	***	***
Operator age	58.80	58.20	59.20	---	---
Beef no	25.70	10.40	7.30	***	***
Dairy no	3.00	4.20	4.80	***	***-
Hogs no	130.10	44.20	34.20	***	***
Chickens no	24.30	115.80	214.90	***	***

Note: Three asterisks indicate significance at the 1% level (t=2.576), two indicate significance at the 5% level (t=1.96), and one indicates significance at the 10% level (t.=1.65).
Source: Model results and USDA data 2002-2014 ARMS.
a.The t-statistics are based on weighting techniques described in Dubman.

Table 9. Cost and Performance Ratios on Farms by Level of Urbanization, 2002-2014 Prairie Gateway

Item	Rural	Medium	High	t-statistic Medium versus Rural[a]	t-statistic High versus Rural[a]
Number of farms	25,792	2.314	1,902		
Percent of farms	77.3	14.1	8.5		
Percent of value of production	91.3	4.6	4.1		
Proportion corn	0.08	0.02	0.03	***	***
Proportion soybeans	0.04	0.01	0.02	***	***
Efficiency Score	0.61	0.56	0.52	***	***
Returns to Scale	0.43	0.37	0.37	***	***
Labor costs per acre ($)	185.87	962.84	1,607.28	***	***
Fuel costs per acre ($)	4.88	6.31	6.96	*	*
Fertilizer costs per acre ($)	51.83	46.87	56.73	***	***
Capital costs per acre ($)	16.86	22.98	25.07	*	*
Pesticide costs per acre ($)	21.22	17.25	24.20	***	***
Corn yield in bushels per acre	154.30	87.70	107.00	***	***
Soybean yield in bushels per acre	46.90	45.90	46.70	---	---
Cotton yield in bushels per acre	632.20	587.40	664.00	***	*
Characteristics					
Price of land per acre	1,219.50	2,235.00	2,921.30	***	***
Acres operated	786.00	244.40	265.60	***	***
Prop Off-farm (percent)	36.30	70.60	65.50	***	***
Return on Assets (percent)	3.30	1.10	2.00	***	***
Household Return (percent)	8.10	8.80	11.00	***	***
Operator age	58.20	57.30	58.00	---	---
Beef no	61.20	26.40	23.00	***	***
Dairy no	2.20	0.30	0.50	***	***
Hogs no	10.50	0.70	0.40	***	***
Chickens no	484.80	53.60	1.20	***	***

Note: Three asterisks indicate significance at the 1% level (t=2.576), two indicate significance at the 5% level (t=1.96), and one indicates significance at the 10% level (t.=1.65).
Source: Model results and USDA data 2002-2014 ARMS.
a.The t-statistics are based on weighting techniques described in Dubman.