Spatial Heterogeneity of Factors Determining Ethanol Production Site Selection, 2000-2007

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Motivation

- Choosing an optimal location is essential for the long-term profitability of an ethanol plant
- The promise of biofuels has rekindled the notion that rural areas may have a comparative advantage due to their access advantage to feedstock materials
- A community could potentially increase comparative advantage by identifying community resources that provide potential investors competitive advantage, and then adjusting those factors
- Understanding the factors that confer comparative advantage with respect to potential ethanol production sites may inform local policy makers about the prospects of recruiting biofuel firms given community resource constraints

Objectives

- Examine the influence that local product and input market factors, transport and utility infrastructure, labor, state policy, and local demographic characteristics within the contiguous forty-eight United States have on the site selection decision of ethanol plants during the years 2000-2007

- Use bivariate probit regression to jointly estimate the location probabilities of established and proposed plants while measuring the factors influencing the likelihood that an ethanol facility locates in a given county

- Use spatial clustering methods to isolate clusters of counties more likely to attract investment from the rapidly expanding ethanol industry

Background

- Production increased over 445 mgy between 2001 and 2006
- Annual growth rate of over 20% between 2001 and 2006
- 20% of the 12,725,000,000 bushels of corn produced in 2006 in the U.S. went to produce ethanol
- Consumer demand for vehicle fuels, Government subsidies, Clean Air Act, Energy Policy Act, increased price of fossil fuels, and MTBE bans drive demand
- Potential mechanism to improve environmental quality, reduce energy concerns, create jobs, and boost income in rural communities

Ethanol Plant Location Choices

- Location of a new ethanol plant may create new jobs, increase the local tax base, and generate community wealth
- Profitable ethanol plants are usually situated near abundant feedstock supplies, reliable transportation systems, adequate water supply and energy sources, and available land
- Long-run survival of an ethanol plant depends on minimizing production costs
  - E.g., minimizing feedstock procurement, natural gas, and labor costs as well as marketing coproducts
- State-wide and federal policies also influence site selection

Ethanol Plant Location Choices

- Location decision is represented as:

  $Z_i = g(\mathbf{M}_i, \mathbf{L}_i, \mathbf{I}_i, \mathbf{P}_i, \mathbf{F}_i)$

- Which represents an indirect cost function:

$$C_m^i\left(q_m^i, \mathbf{w}^i, \mathbf{p}; \boldsymbol{\alpha}, \boldsymbol{\theta}\right) = q_m^i\left(\sum_k w_k^i \alpha_k^{-1} - \sum_l \theta^l p_{(i,j)}^l\right)$$

  - This cost function is not directly observed but it is assumed that firms engage in cost minimization

Ethanol Plant Location Choices

- The location probability of plant establishments is:

$$Z_i^* = \Pr[EST_i = 1] = \Phi({}^{EST}\mathbf{x}_i'\boldsymbol{\beta}_{EST})$$

- The location probability of plant announcements is:

$$Z_i^* = \Pr[ANN_i = 1] = \Phi({}^{ANN}\mathbf{x}_i'\boldsymbol{\beta}_{ANN})$$

- A bivariate probit model is used to jointly estimate the location probabilities of established and proposed plants,

$$Z_i^* = \Pr[ANN_i = 1, EST_i = 1] = \Phi_{BVN}({}^{EST}\mathbf{x}_i'\boldsymbol{\beta}_{EST}, {}^{ANN}\mathbf{x}_i'\boldsymbol{\beta}_{ANN}, \rho)$$

Empirical Model and Location Factors

- County-level factors are regressed against binary variables indicating where ethanol plants became operational from 2000-2007 and ethanol plant location announcements between the same periods

- $\Pr[Z_i^t = 1] = \Phi_{BVN}(\ IRR_i,\ IRR_i * \mathbf{M}_i,\ IRR_i * \mathbf{L}_i,\ IRR_i * \mathbf{I}_i,\ IRR_i * \mathbf{F}_i,\ IRR_i * \mathbf{P}_i,\ \mathbf{M}_i,\ \mathbf{L}_i,\ \mathbf{I}_i,\ \mathbf{F}_i,\ \mathbf{P}_i,$ Regional fixed effects; $\rho)$

Descriptive Statistics of Location Determinants

Variable		Mean	Standard Deviation
Location Announcements (2000-2007)		0.020	0.140
Active Ethanol Plants (2000-2007)		0.035	0.183
FARMPROP	Farm proprietor income/nonfarm proprietor income (2000)	0.190	0.557
CATTLE	Cattle, plus surrounding counties (1000,000s head)	2.007	2.045
CORN	Average total corn production plus surrounding counties (1990-2000) (100,000s bushels)	171.266	217.756
STORE	Farm product warehousing operations (Location Quotient) (2000)	2.117	13.963
NATGAS	Natural gas distribution centers (Location Quotient) (2000)	3.308	8.114
GAS	Gas stations, plus surrounding counties (2000)	6.894	3.429
ESTAB	Existing ethanol plant before 2000 (1 = yes)	0.010	0.106
HERFEMP	Employment concentration index, 2000 (between [0,1])	0.121	0.052
WAGE	Average wage per worker ($), 2000	12.307	2.761
HS00	% with highschool diploma, 2000	77.321	8.732
TRUCKLQ	Trucking companies (Location Quotient), 2000	2.076	1.897
ROAD	Road density (road miles/county area)	0.457	0.272

Descriptive Statistics of Location Determinants

Variable		Mean	Standard Deviation
RAIL	Rail density (rail road miles/county area)	0.307	0.402
RIVER	River adjacency	0.326	0.469
FISC	Per capita income taxes/county expenditures, 2000	0.337	0.229
TAX	State excise tax incentive (2001) (1 = yes)	0.133	0.339
PRODCR	Ethanol producer credit program (2001) (1 = yes)	0.233	0.423
MTBE	Methyl tertiary-butyl ether ban, 2000 (1 = yes)	0.185	0.388
IRR2000	Waldorf's (2006) 2000 rurality index (between [0,1])	0.501	0.177
HLAND	Heartland (1 = yes)	0.178	0.382
NOCRES	Northern Crescent (1 = yes)	0.138	0.345
FRUIT	Fruitful Rim (1 = yes)	0.091	0.288
NOGRTPL	Northern Great Plains (1 = yes)	0.058	0.235
PRGATE	Prairie Gateway (1 = yes)	0.128	0.334
BRANGE	Basin and Range (1 = yes)	0.064	0.245
MISSPORT	Mississippi Portal (1 = yes)	0.054	0.226
SOSEA	Southern Seaboard (1 = yes)	0.155	0.362

Data

- Renewable Fuels Association (RFA), 2007
- National Agricultural Statistics Service (NASS), 2000
- United States Census Bureau, 2000
- United States Department of Energy, 2001
- GIS/ESRI
- United States Census County Business Pattern files, 2000
- Office of Management and Budget (OMB), 2007
- Economic Research Service (ERS), 2000

Estimation Procedures

- A Wald test is used to test the equality of the IRR slope and intercept coefficients
  - The null hypothesis that location determinants were geographically stationary, i.e. all IRR interactions equal 0, is tested
  - Rejected at the 5% level, therefore IRR interactions are included
- A Wald test is used to test independence between 1st and 2nd stage decisions of ethanol plant location decisions
  - The null hypothesis that regions did not influence the 2nd stage decision of ethanol plant location decisions is tested
  - Accepted at the 5% level and suggests that regional coefficients may be omitted

Bivariate Probit Estimates, 2000-2007

	Announced		Established	
Variable	Estimate	Tvalue	Estimate	Tvalue
CONSTANT	1.379	0.776	1.499	0.929
FARMPROP	2.408	3.459	2.472	3.875
CATTLE	-0.045	-0.729	0.151	2.647
CORN	0.002	3.056	0.002	4.412
STORE	-0.009	-0.977	-0.044	-1.960
NATGAS	0.036	1.901	0.003	0.114
GAS	-0.104	-2.233	0.120	2.810
ESTAB	-7.376	-3.604	0.492	0.666
HERFEMP	8.078	2.975	-0.287	-0.097
WAGE	-0.163	-3.133	0.022	0.648
HS00	-0.021	-1.083	-0.056	-3.010
TRUCKLQ	0.424	3.101	0.303	2.452
ROAD	-0.675	-1.158	-0.766	-1.531
RAIL	-0.870	-2.015	-0.471	-1.307

Note: Tvalues 1.645, 1.961, and 2.577 significant at the 10%, 5%, and 1% level respectively

Bivariate Probit Estimates, 2000-2007

	Announced		Established	
Variable	Estimate	Tvalue	Estimate	Tvalue
RIVER	0.831	3.770	-0.155	-0.741
FISC	-1.442	-2.166	0.991	1.705
TAX	-0.282	-0.811	0.122	0.432
PRODCR	-0.049	-0.154	-0.342	-1.229
MTBE	-0.007	-0.024	1.110	4.623
IRR2000	-13.457	-3.991	-12.254	-4.020
IRR FARMPROP	-3.091	-3.301	-3.044	-3.546
IRR CATTLE	0.218	1.976	-0.135	-1.324
IRR CORN	-0.004	-3.649	-0.003	-3.261
IRR STORE	0.021	1.148	0.070	1.952
IRR NATGAS	-0.036	-1.329	-0.028	-0.672
IRR GAS	0.132	2.079	-0.118	-2.025
IRR ESTAB	1.220	0.312	-1.709	-1.096
IRR HERFEMP	-11.452	-2.451	-10.589	-1.927

Note: Tvalues 1.645, 1.961, and 2.577 significant at the 10%, 5%, and 1% level respectively

Bivariate Probit Estimates, 2000-2007

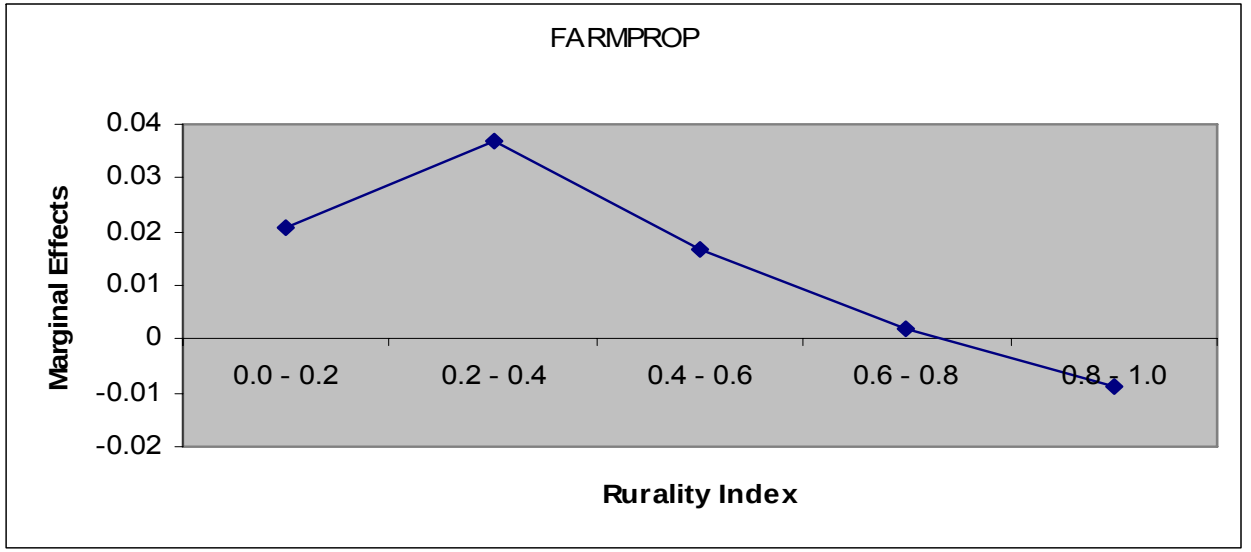
	Announced		Established	
Variable	Estimate	Tvalue	Estimate	Tvalue
IRR WAGE	0.251	2.550	-0.093	-1.224
IRR HS00	0.118	3.088	0.165	4.587
IRR TRUCKLQ	-0.534	-2.489	-0.363	-1.961
IRR ROAD	0.284	0.206	2.332	1.987
IRR RAIL	4.988	4.456	2.221	2.284
IRR RIVER	-1.781	-3.771	-0.088	-0.211
IRR FISC	1.317	1.087	-2.810	-2.516
IRR TAX	1.375	2.202	0.514	1.025
IRR PRODCR	0.065	0.110	1.549	2.955
IRR MTBE	0.737	1.446	-1.113	-2.480
N	3064			
Log likelihood	-584.152			
ρ	-0.988			
Pseudo R^2	0.229			

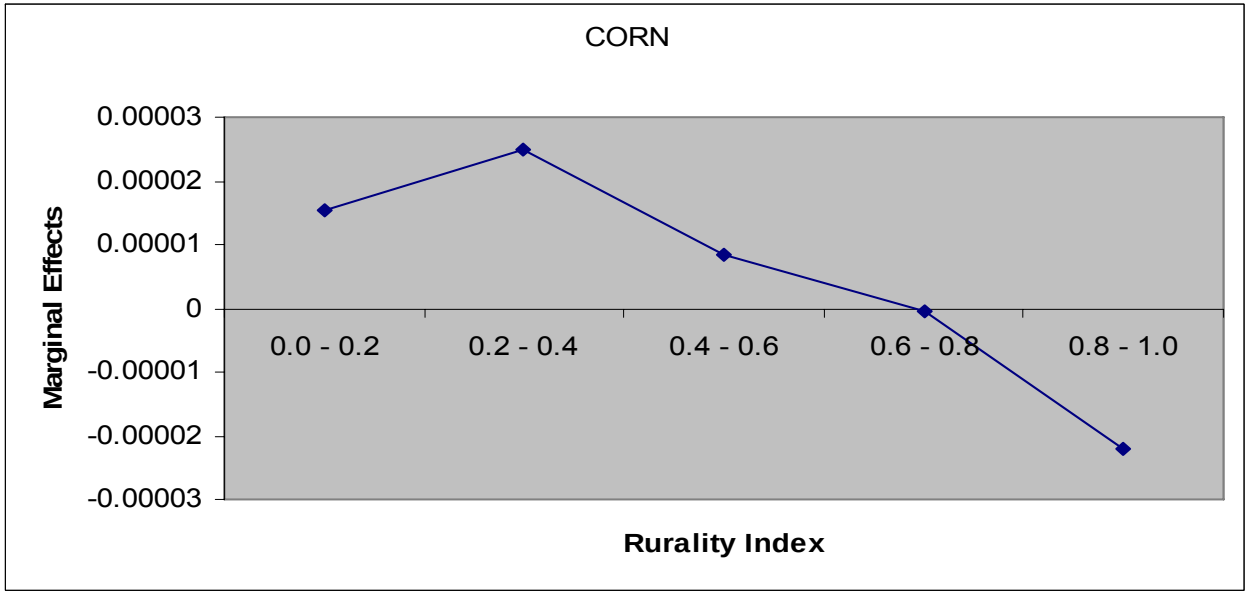
Note: Tvalues 1.645, 1.961, and 2.577 significant at the 10%, 5%, and 1% level respectively

Marginal Effects for Active Plants

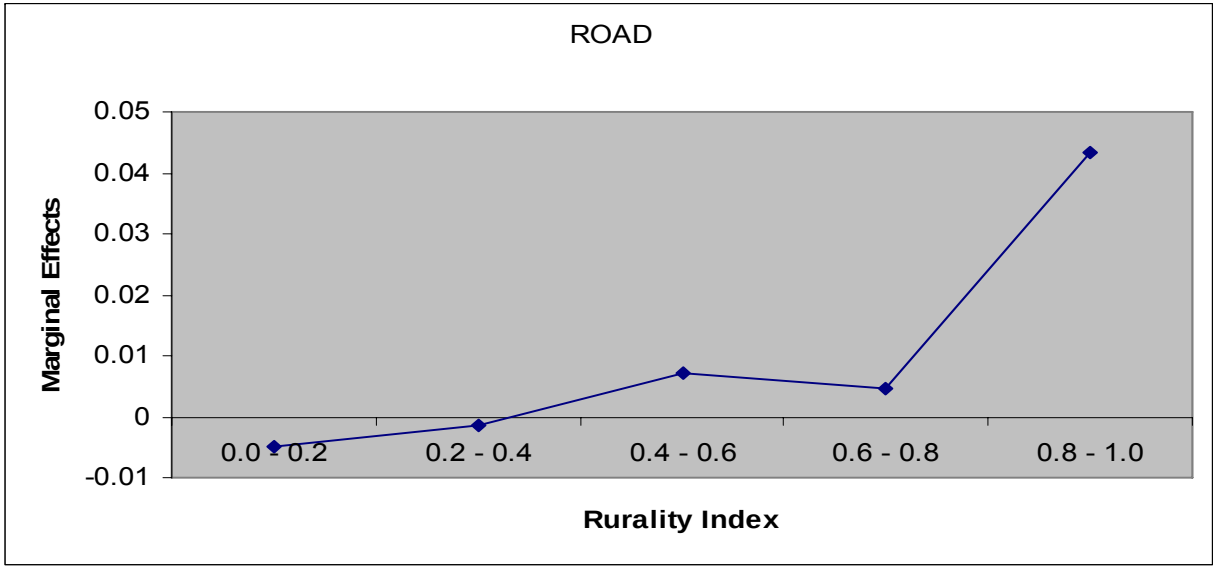
Active plants	----------Rurality index----------				
Variable	0.0 - 0.2	0.2 - 0.4	0.4 - 0.6	0.6 - 0.8	0.8 - 1.0
GAS	0.001027	0.001994	0.001082	0.000195	0.000443
FARMPROP	0.020623	0.036848	0.016915	0.001786	-0.008689
HS00	-0.000377	-0.000154	0.000473	0.000312	0.003017
HERF00	-0.012808	-0.081871	-0.099345	-0.040246	-0.319396
STORE	-0.000353	-0.000547	-0.000164	0.000025	0.000608
ROAD	-0.005071	-0.001575	0.007114	0.004527	0.043349
RAIL	-0.002365	0.004622	0.011387	0.005666	0.049718
TRUCK	0.002537	0.004587	0.002162	0.000255	-0.000774
TXEXC	0.006752	0.003491	-0.007374	-0.005103	-0.050047
CORN	0.000016	0.000025	0.000008	-0.000001	-0.000022
PRODCR	-0.001388	0.003350	0.013306	0.012205	0.012079
MTBE	0.038224	0.045907	0.019838	0.002861	0.003977

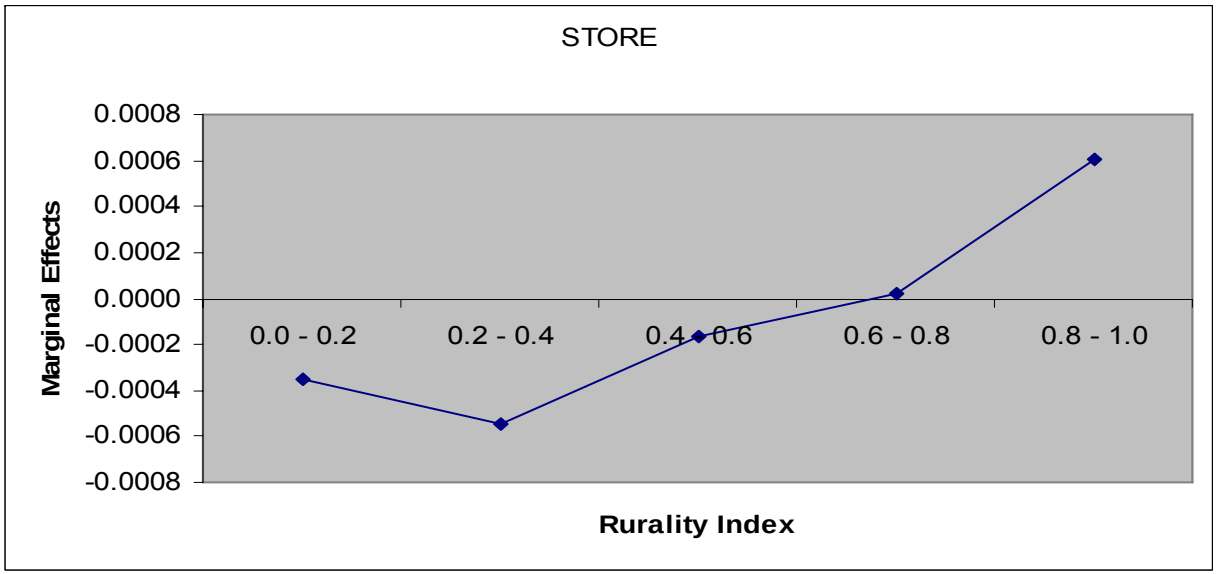
Marginal Effects for Active Plants





Marginal Effects for Active Plants

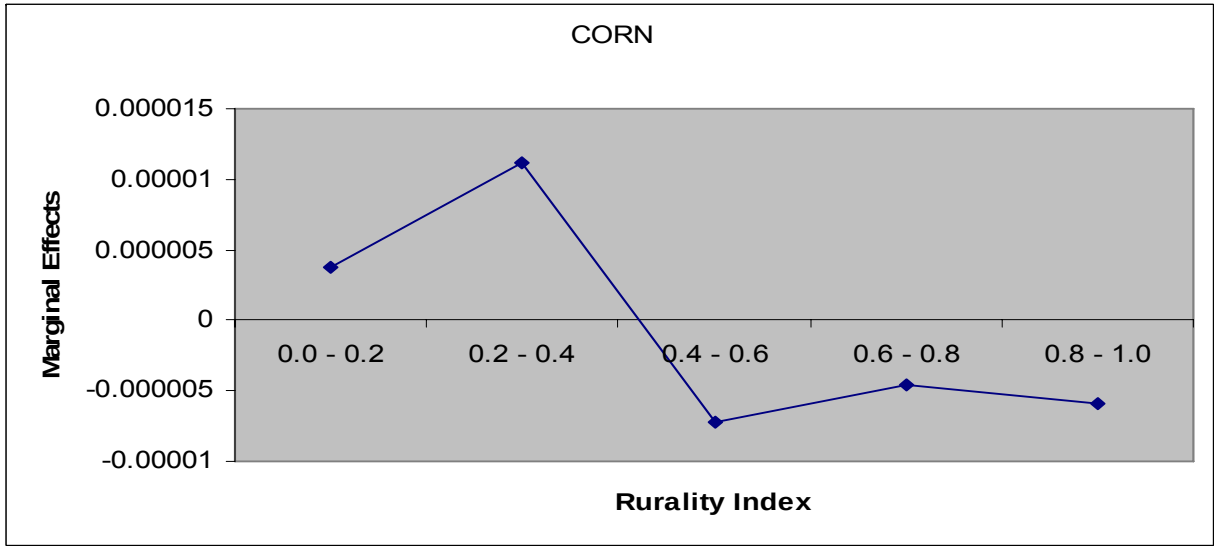


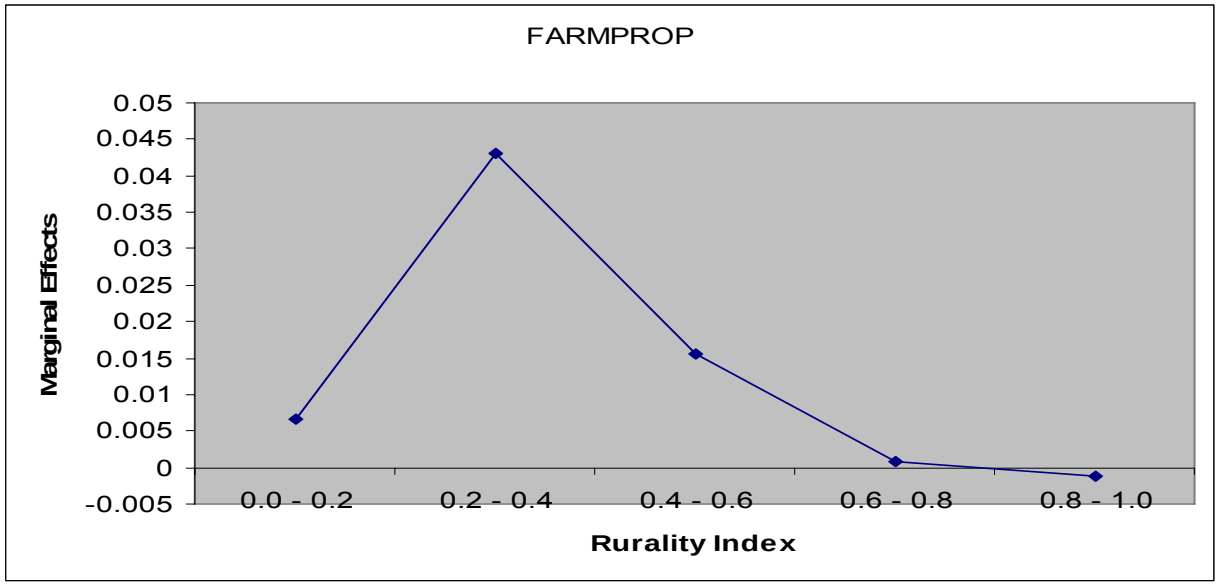


Marginal Effects for Announced Plants

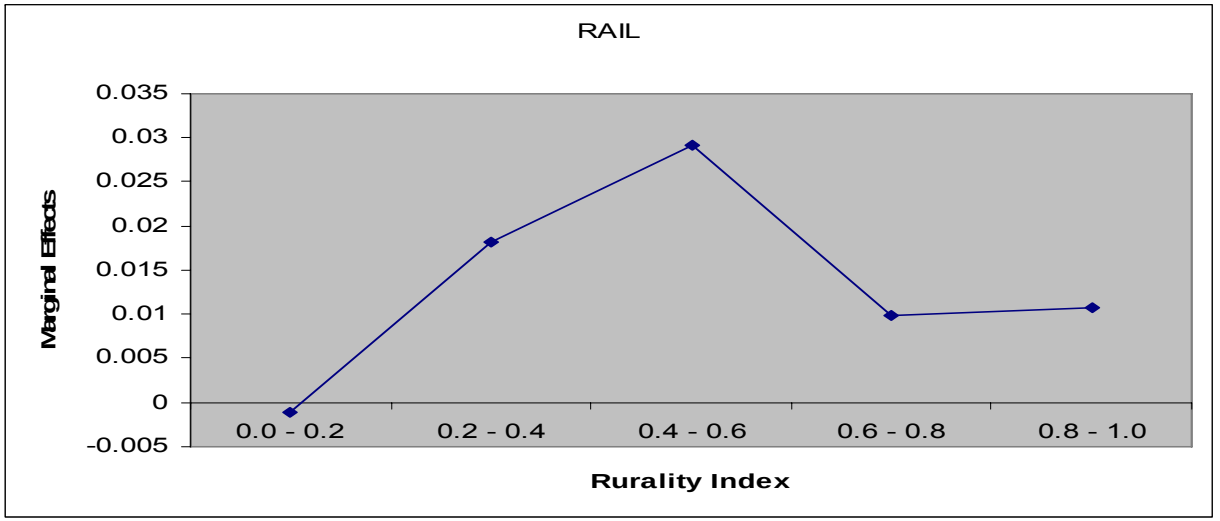
Plant announcements	----------Rurality index----------				
Variable	0.0 - 0.2	0.2 - 0.4	0.4 - 0.6	0.6 - 0.8	0.8 - 1.0
GAS	-0.000291	-0.001872	-0.000680	-0.000044	0.000044
FARMPROP	0.006735	0.043122	0.015460	0.000924	-0.001105
HS00	-0.000030	0.000412	0.000675	0.000232	0.000250
HERF00	0.022244	0.135197	0.042161	0.000233	-0.006582
RAIL	-0.001190	0.018250	0.029116	0.009924	0.010690
TRUCK	0.001188	0.007676	0.002811	0.000189	-0.000168
RIVER	0.006130	0.012140	-0.000995	-0.000874	-0.000820
CATTLE	-0.000075	0.000589	0.001143	0.000406	0.000446
CORN	0.000004	0.000011	-0.000007	-0.000005	-0.000006
TAX	-0.000373	0.004407	0.012129	0.007710	0.013862

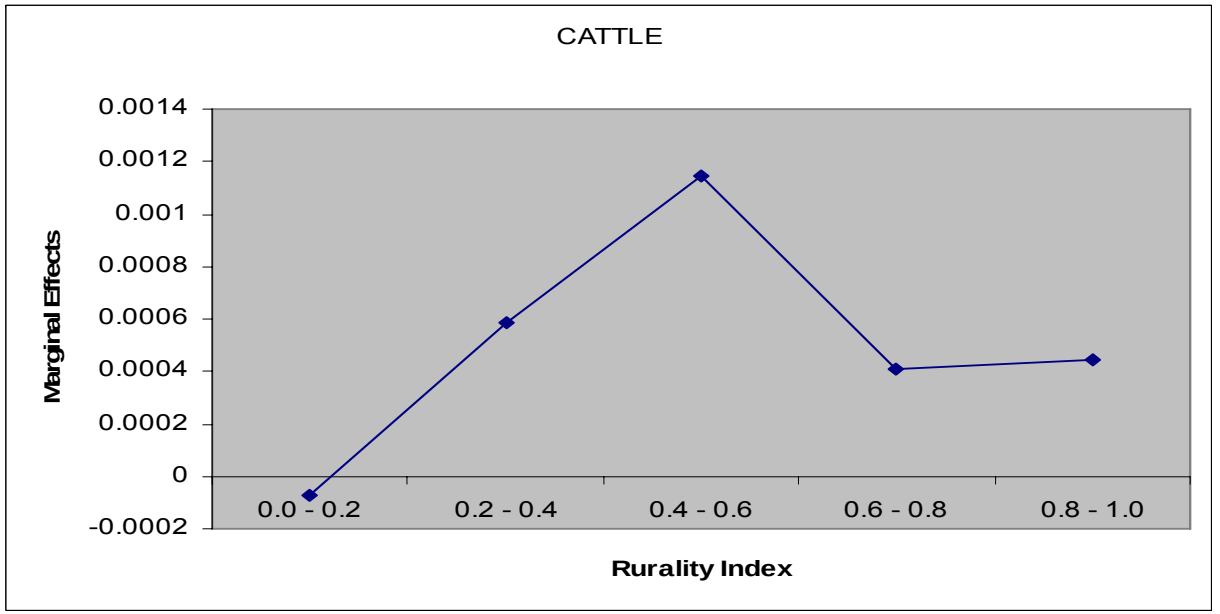
Marginal Effects for Announced Plants



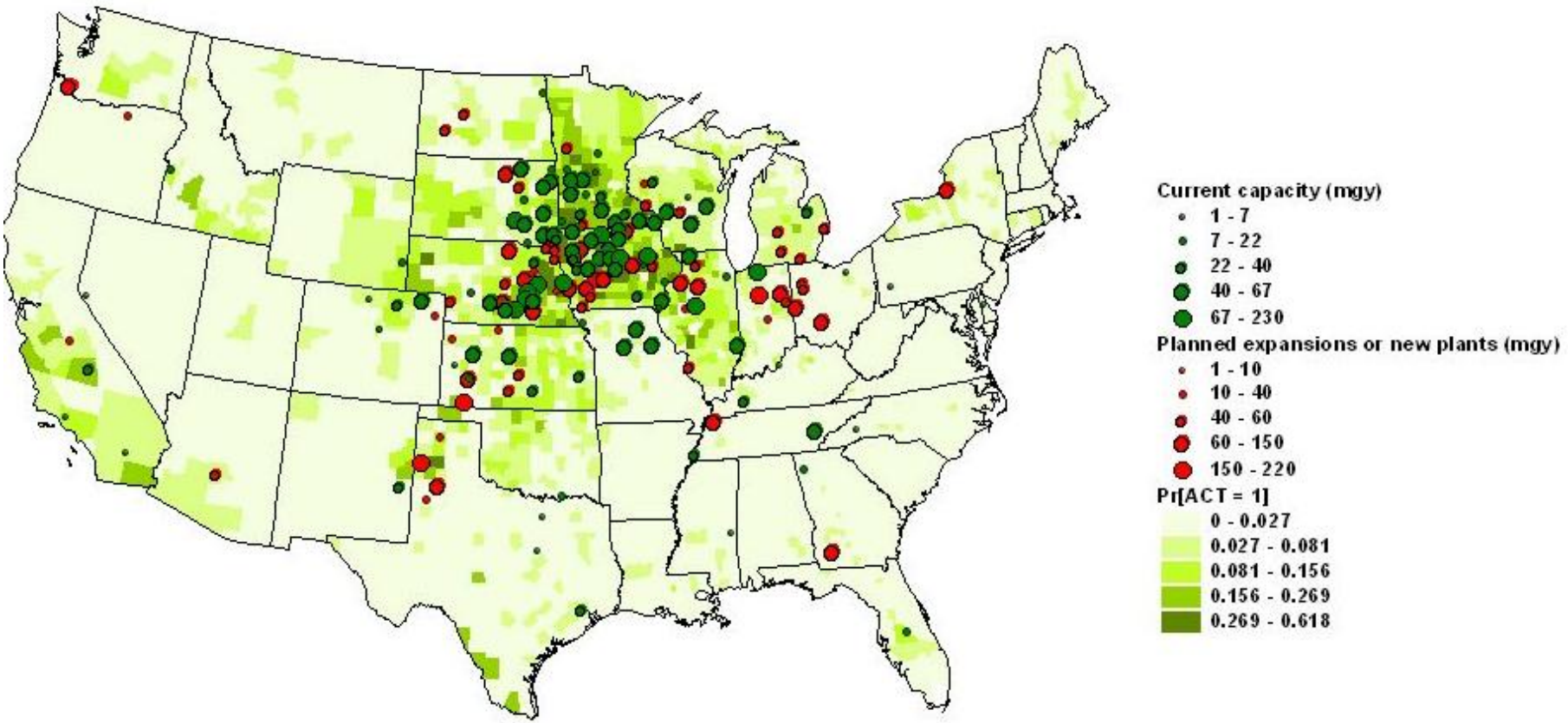


Marginal Effects for Announced Plants

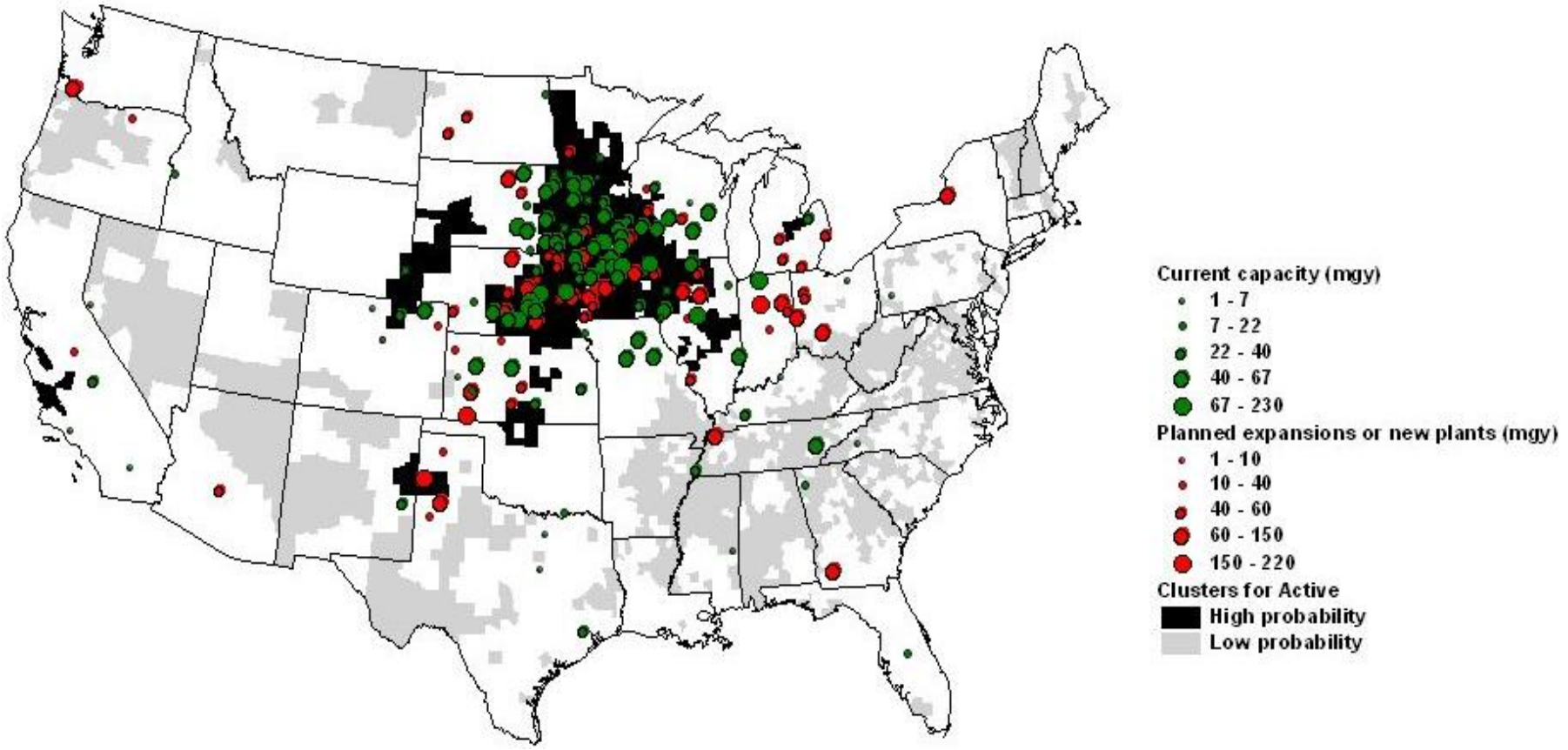




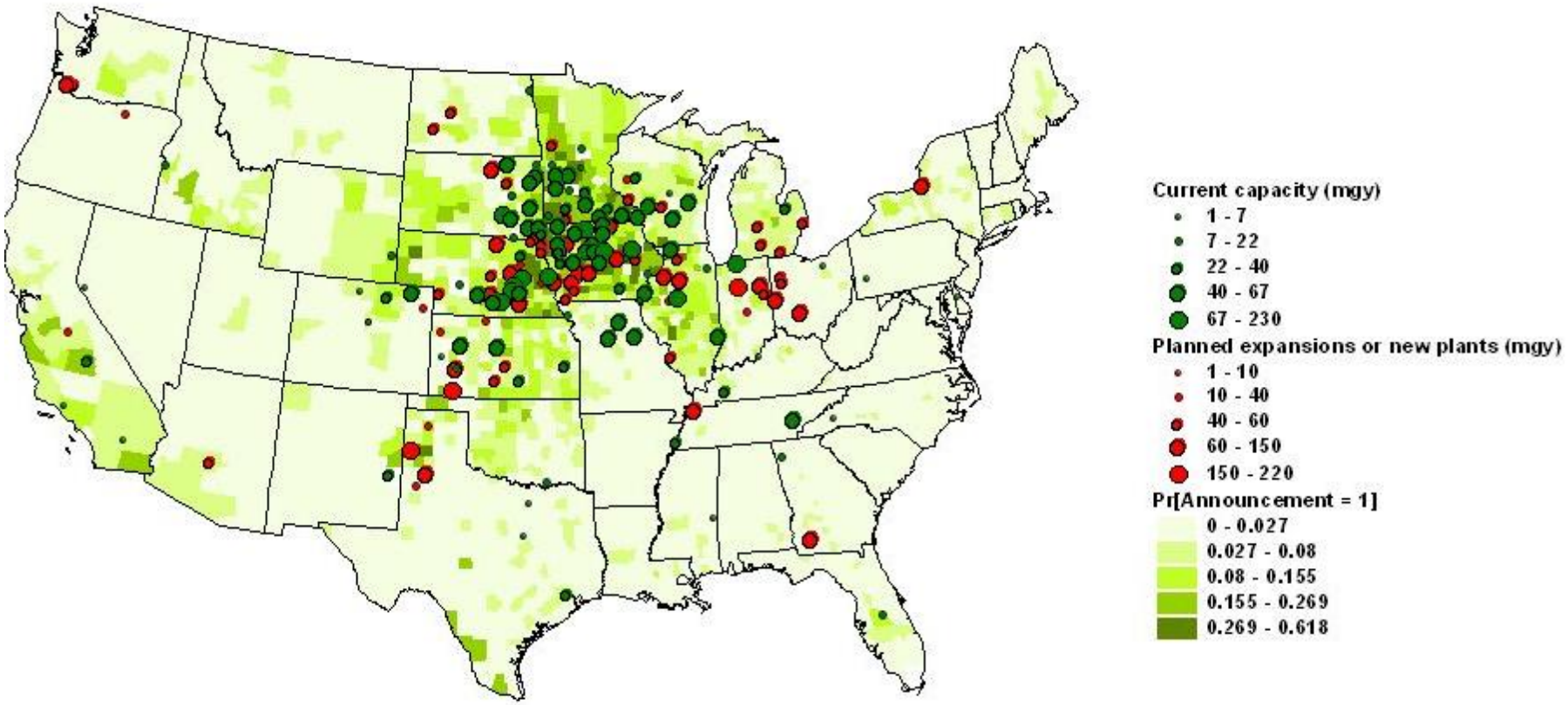
Spatial distribution of estimated location probabilities for active ethanol plants



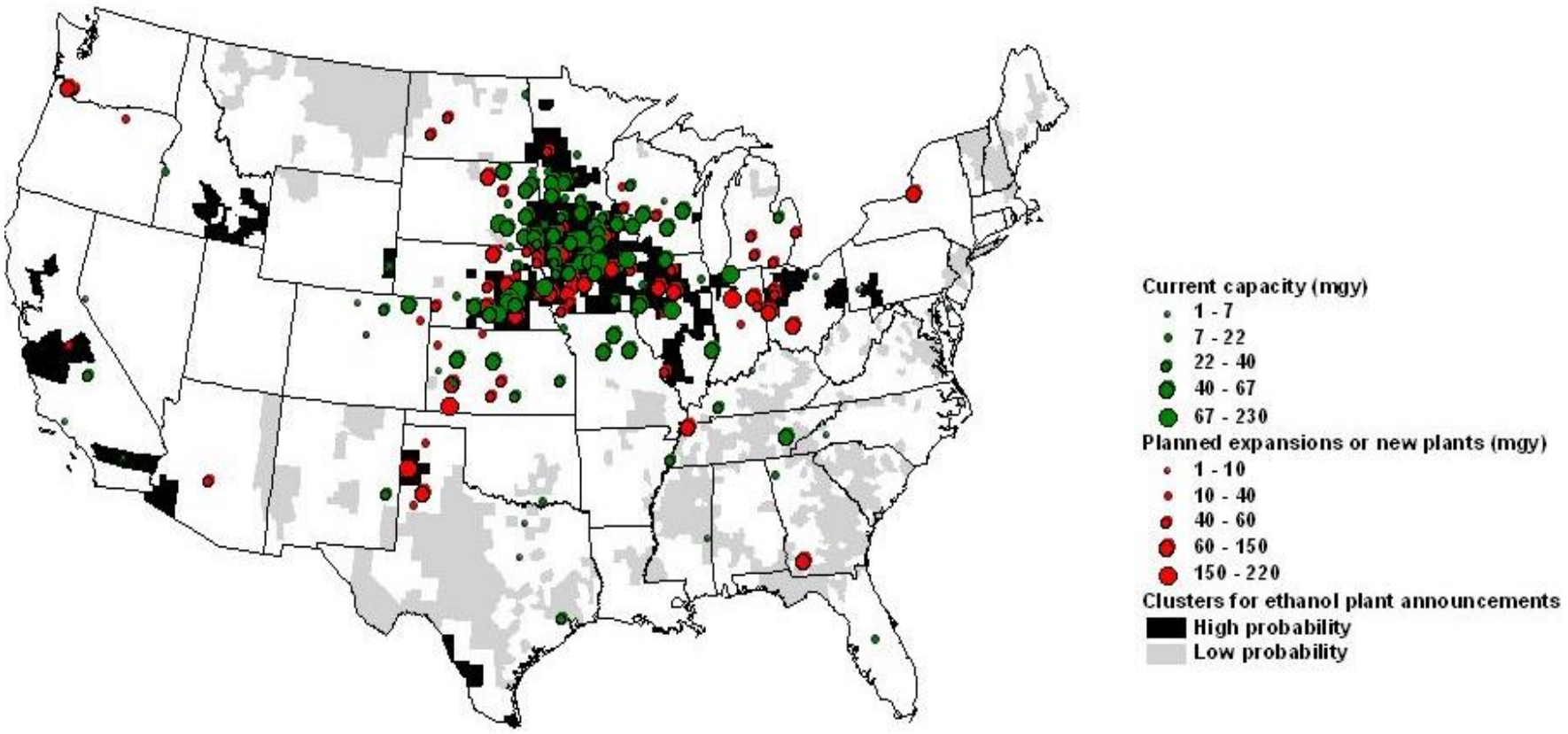
Active Plant Location Probability Clusters



Spatial distribution of estimated location probabilities of ethanol plant location announcements

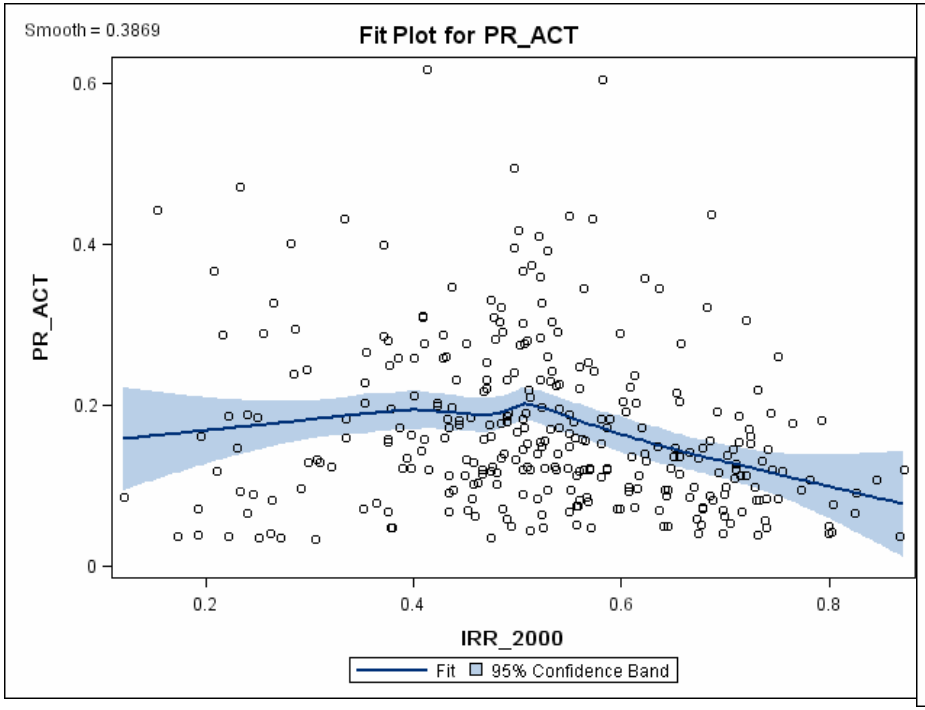


Announced plant location probability clusters

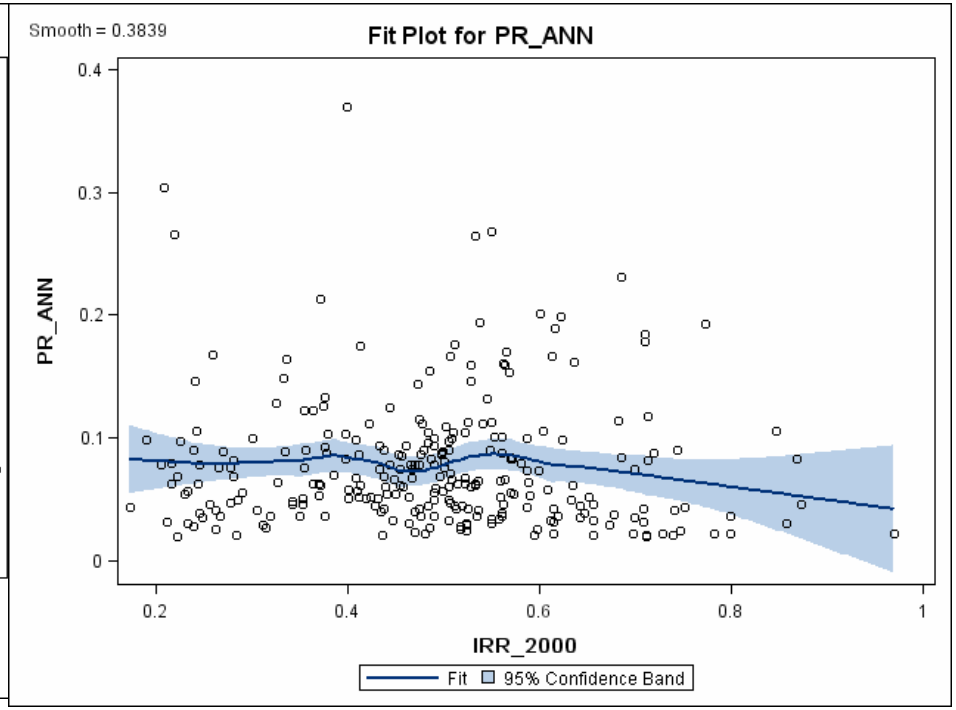


Loess Curves

Active Plants



Announced Plants



Conclusions and Future Studies

- Significance of some variables varied depending on the interaction with the rurality index, the announced status of the variable, or active status of the variable
- Extremely rural areas may be a deterrent for potential ethanol production in some instances
- The primary drivers behind the decision to locate an ethanol plant are feedstock access and the absence of previously established ethanol plants
- While the results appear to be encouraging for some rural areas, rurality should still be kept in perspective
- Future studies analyzing location determinants will prove interesting as alternative feedstocks become available and the ethanol industry approaches saturation