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Roles of Systemic Risk and Premium Subsidies in Choices between Area and Individual Insurance Contracts

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Motivation

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- Many countries have sought to establish crop insurance contract offerings to crop producers to help them hedge against agriculture risks.
  - The U.S., Canada, the European Union, etc..
  - Brazil, India, the Southeast Asia, etc..

- These efforts have been confounded by information problems.
  - Adverse selection & Moral hazard
  - High administration costs.

- Large government subsidies are required to maintain the operation of crop insurance market.
  - In the U.S., the Federal Crop Insurance Program (FCIP) has accounted for about $7.2 billion annual net costs over the period of 2007 through 2016.

Motivation

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- In order to reduce costs caused by information asymmetry, program designers would prefer to base payments on off-farm information.

- This preference has motivated interests in area yield insurance (Halcrow, 1949; Miranda, 1991; Smith, et al., 1994).
    - Area yield is highly correlated with individual yields, easier to observe, less costly to collect, and largely unaffected by individual farmer's behaviors.

- In 1993, the U.S. Department of Agriculture (USDA) initiated a pilot test of area yield insurance program, known as Group Risk Plan (GRP).
    - Barnett et al. (2005) find that GRP outperformed MPCI in risk reduction for some crops and regions.
    - GRP was replace by Area Risk Protection (ARP) in 2014.

- The take-up rate of area insurance, however, remains low.

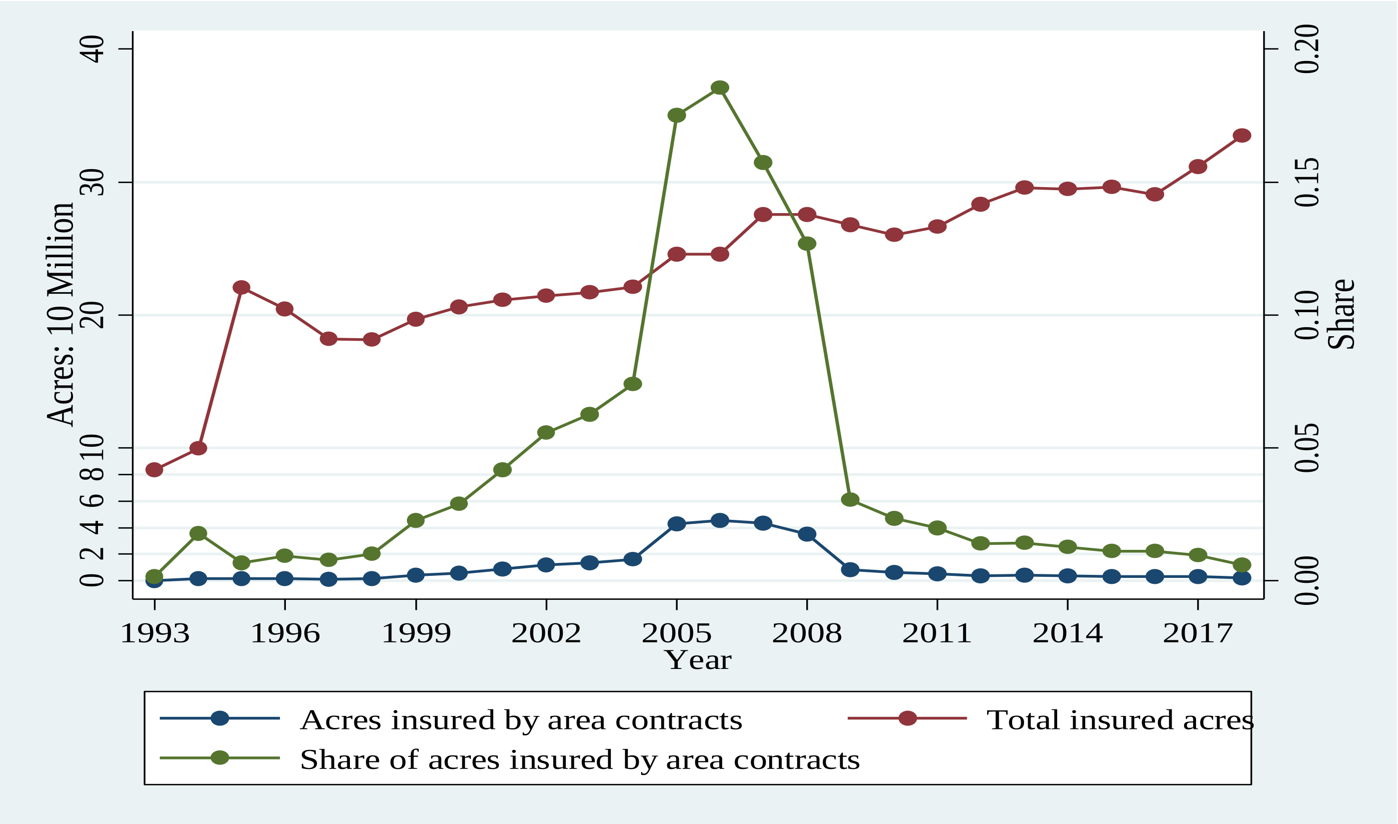

Figure 1. Share of area insurance insured acres in total insured acres, 1993-2018

Motivation

- The low participation rate of area yield insurance might be explained by the imperfect of correlation between individual yield and area yield (Clarke, 2016).
  - Area insurance participants may not receive indemnities when farm yields are very poor but area yields are not.

- Area insurance can only hedge against the risk that is systemic with area yield, which is referred as the systemic risk (Miranda, 1991; Mahul, 1999).

- However, few studies have measured the systemic risk components in crop production.
  - Miranda (1991), Smith et al. (1994) and Barnett et al. (2005).
  - Claassen and Just (2011).
  - Zulauf et al. (2013).

Motivation

- In this paper, we measure the systemic risk in non-irrigated corn production in 589 counties across the Midwest.
- Based on Miranda's (1991) single factor capital market model, we characterize systemic risk as the proportion of unit yield variation that can be explained by county yield variation.
- We further decompose systemic risk into three components to investigate how it is determined by the correlation between individual yield and area yield.
- We also model systemic risk in terms of some county geographic attributes to examine how systemic risk is determined by county growing conditions.

Motivation

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- Besides systemic risk, premium subsidies may also play an important role in determining the demand of area insurance.
  - The substantial decline in the demand of area insurance in 2009 coincides with the reduction in area insurance subsidy rates proposed by the 2008 Farm Bill.

- Under actuarially fair premiums, producers will demand full individual insurance and no area insurance (Deng et al., 2007; Bulut et al., 2012).

- The introduction of premium subsidies may induce producers to choose area insurance over individual insurance.
  - Under actually subsidized premiums, GRP would be preferred to MPCI by cotton producers in Georgia and South Carolina (Deng et al, 2007).

- The take-up rate of area yield insurance, however, remains low.

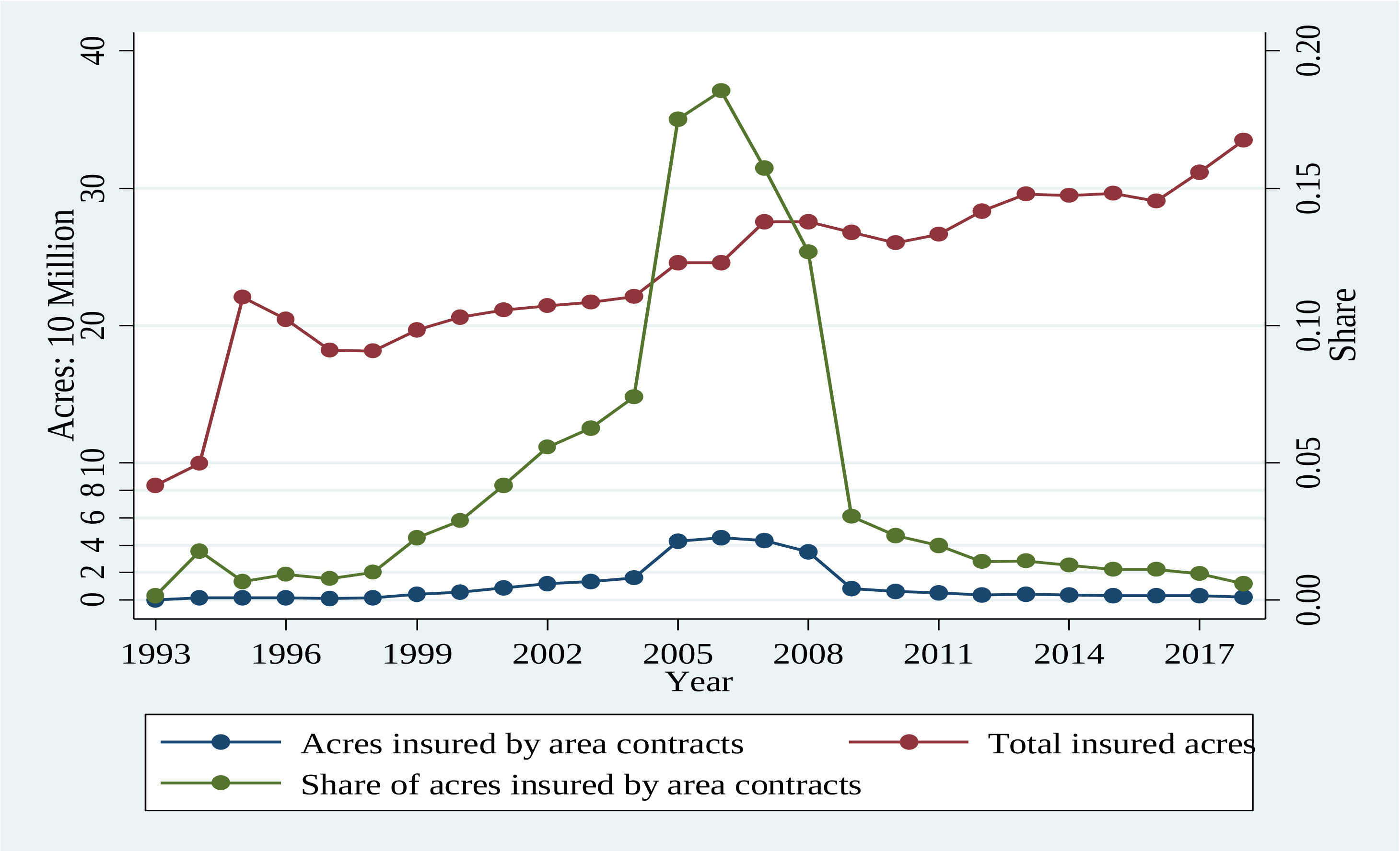

Figure 1. Share of area insurance insured acres in total insured acres, 1993-2018

- Question remains open that whether the current area yield subsidy rate discourages most producers to choose area insurance.

- In this paper, we calibrate the threshold area subsidy rate (TASR), below which even risk neutral producers will always choose individual yield insurance over area yield insurance.
  - Thus, producers may choose area insurance over individual insurance only if his/her TASR is lower than the current area yield subsidy rate.

- We also investigate the relationship between TASR and systemic risk.
  - Area insurance are mostly likely to attract producers with high systemic risk and low TASR.

- **Measure systemic risk**
- The relationship between individual yield and county yield is given by Miranda' (1991) one factor capital market model:

$$\tilde{y}_i = \mu_i + \underbrace{\beta_i(\tilde{y}_c - \mu_c)}_{\text{County yield related part}} + \underbrace{\theta_i \varepsilon_i}_{\text{County yield unrelated part}}, \quad (1)$$

  - $\tilde{y}_i$ and $\tilde{y}_c$ are random unit yield and county yield.
  - μ_i and μ_c are the expected unit yield and county yield.
  - $\mu_i = E(\tilde{y}_i)$, $\mu_c = E(\tilde{y}_c)$.
  - $E(\varepsilon_i) = 0$, $Var(\varepsilon_i) = 1$ ⟹ $Var(\theta_i\varepsilon_i) = \theta_i^2$.
  - ε_i is uncorrelated with $\tilde{y}_c$, and let $Var(\tilde{y}_c) = \sigma_c^2$

⟹ $Var(\tilde{y}_i) = Var[\beta_i(\tilde{y}_c - \mu_c) + \theta_i\varepsilon_i] = \beta_i^2\sigma_c^2 + \theta_i^2$

- **Measure systemic risk**
- Systemic risk, labelled as R_i^2, is then modeled as

$$R_i^2 = \frac{\beta_i^2 \sigma_c^2}{\beta_i^2 \sigma_c^2 + \theta_i^2} = \frac{1}{1 + \tau_i^2}, \quad (2)$$

where $\tau_i^2 = \theta_i^2 / \beta_i^2 \sigma_c^2$.

- Thus, systemic risk is jointly determined by three components:
  - Unit yield's sensitivity to county yield, β_i^2.
  - County yield variance, σ_c^2.
  - Idiosyncratic yield variance θ_i^2.

- **Systemic risk and county growing conditions**
- By $R_i^2 = 1/(1+\tau_i^2)$, then

$$R_i^2/(1-R_i^2) = 1/\tau_i^2 = \beta_i^2 \sigma_c^2/\theta_i^2.$$

- Taking the natural log on both sides,

$$\ln\left[R_i^2/(1-R_i^2)\right] = \ln\left[\beta_i^2(Z_c)\right] + \ln[\sigma_c^2(Z_c)] - \ln\left[\theta_i^2(Z_c)\right], \qquad (3)$$

- We allow β_i^2, σ_c^2, and θ_i^2 all to be functions of Z_c, which is a set of county growing condition variables.

- **Identify TASR**
- Under actuarial fair premiums, the subsidy level

$$\hat{s}_c = s_i E(\tilde{n}_i)/E(\tilde{n}_c) \quad (4)$$

constitutes the lower bond on area insurance subsidy rate to attract producers.

  - s_i is the premium subsidy rate of individual insurance
  - $E(\tilde{n}_i)$ and $E(\tilde{n}_c)$ are the expected indemnities of individual insurance and area insurance.

- Can show that when $s_c < \hat{s}_c$, $E(\tilde{y}_c^{net}) < E\left(\tilde{y}_i^{net}\right)$.
  - $E\left(\tilde{y}_i^{net}\right)$, $E(\tilde{y}_c^{net})$ are the expected net returns of purchasing individual insurance and area insurance.

- We call $\hat{s}_c$ the threshold area subsidy rate (TASR), below which even risk neutral growers will always choose MPCI over ARP.

Data and Variables

- Unit corn yield data are from the 1998-2007 unit-level Risk Management Agency (RMA) records and county yield data are from National Agricultural Statistical Service (NASS).
  - 215779 units in 589 counties across 12 major corn production states.

- Weather data are from National Oceanic and Atmospheric Administration (NOAA). Weather variables are:
  - Heat conditions: Growing degree days, G_c; Stress degree days, S_c.
  - Precipitation, P_c.
  - Each variable is calculated as the 30-year average (1978-2007). Variances are also calculated.

- Land quality data are from National Resource Conservation Service (NRCS).
  - County land quality, L_c, is defined as the fraction of land that is in land capability classes (LCC) I or II in that county.

Data and Variables

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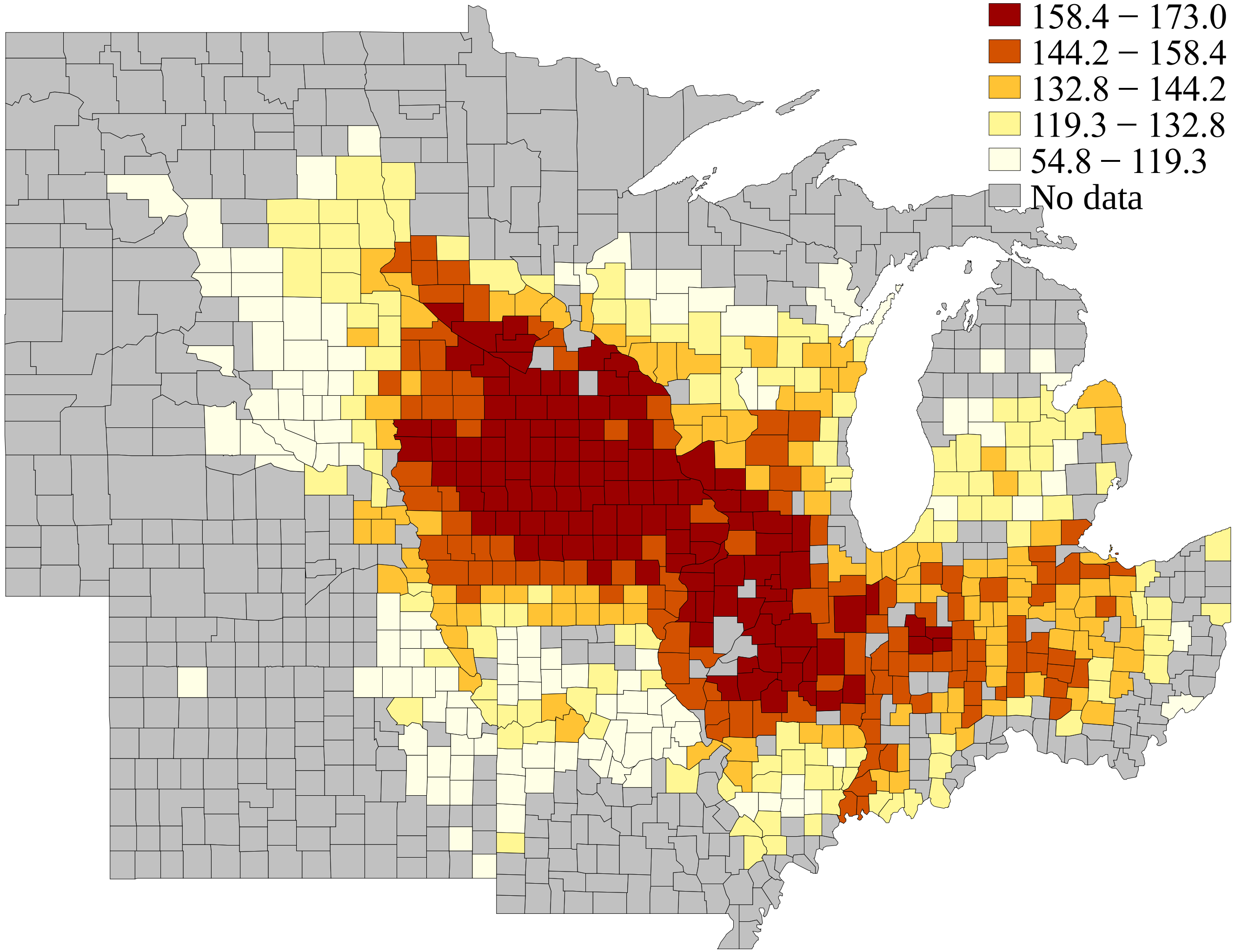

Figure 2. Geographic distribution of county average yield across 1998-2007

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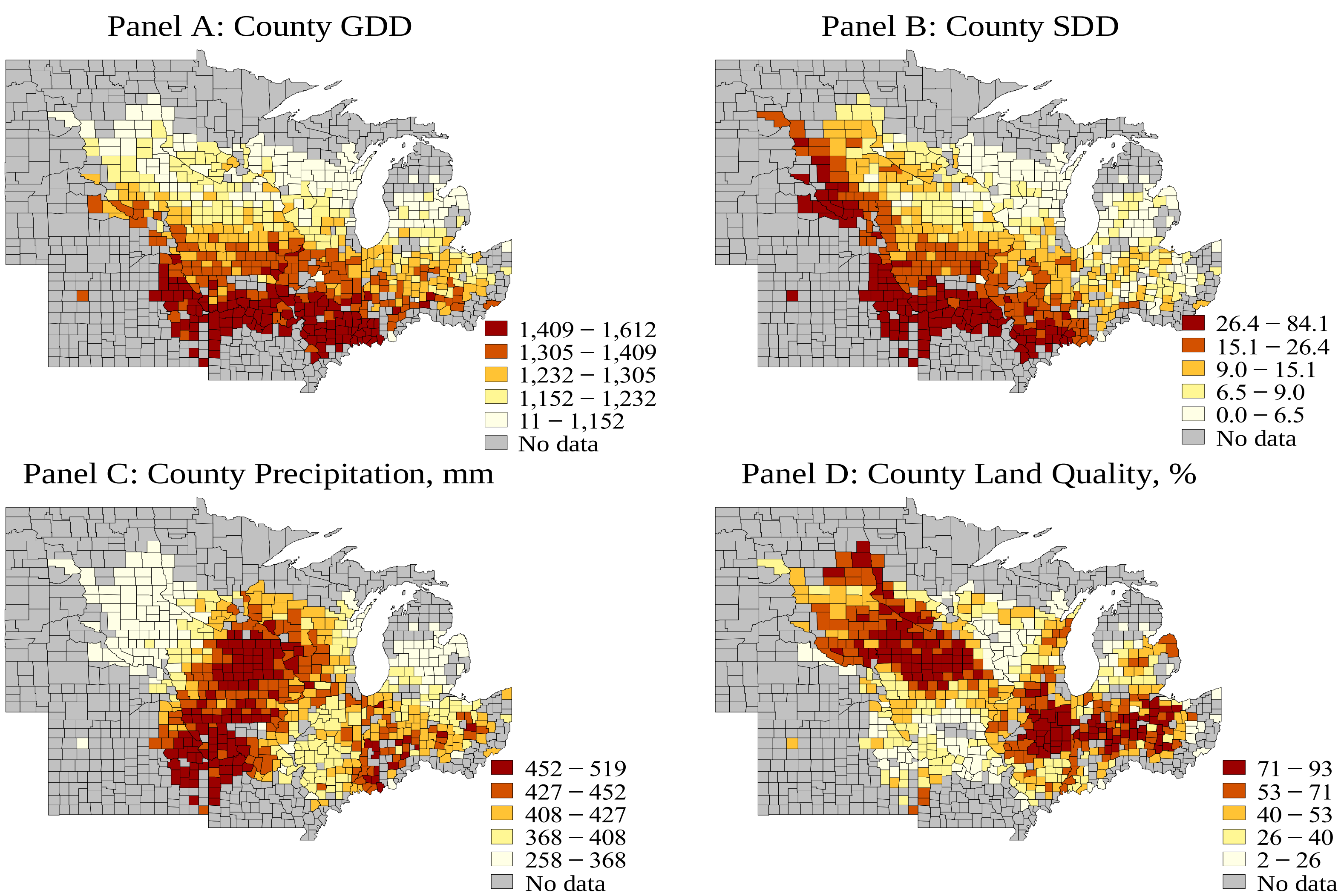

Figure 3. Geographic distribution of county weather conditions and land quality

- **Measure Systemic risk**

- The empirical model to estimate the systemic risk is given by

$$\tilde{y}_i - \mu_i = \alpha_c + \beta_c(\tilde{y}_c - \mu_c) + \theta_i \varepsilon_i. \quad (5)$$

- Each unit only has 10 year observations.
- We estimate the county-level systemic risk instead of estimating unit-level systemic risk using pooled unit-level data for each county.

- **County-level systemic risk is measured by the R-squared of Pooled OLS estimation of (5).**

Empirical Results

Table 1. Descriptive statistics for county systemic risk and its components

	Obs	Mean	Std	Min	Max
Systemic risk, R_c^2	589	0.36	0.16	0	0.79
Unit yield sensitivity, β_c	589	1.04	0.24	-0.39	1.95
Unit idiosyncratic yield variance, θ_i^2	589	580.9	224.2	82.23	1640
County yield variance, σ_c^2	589	412.5	262.5	56.46	1890

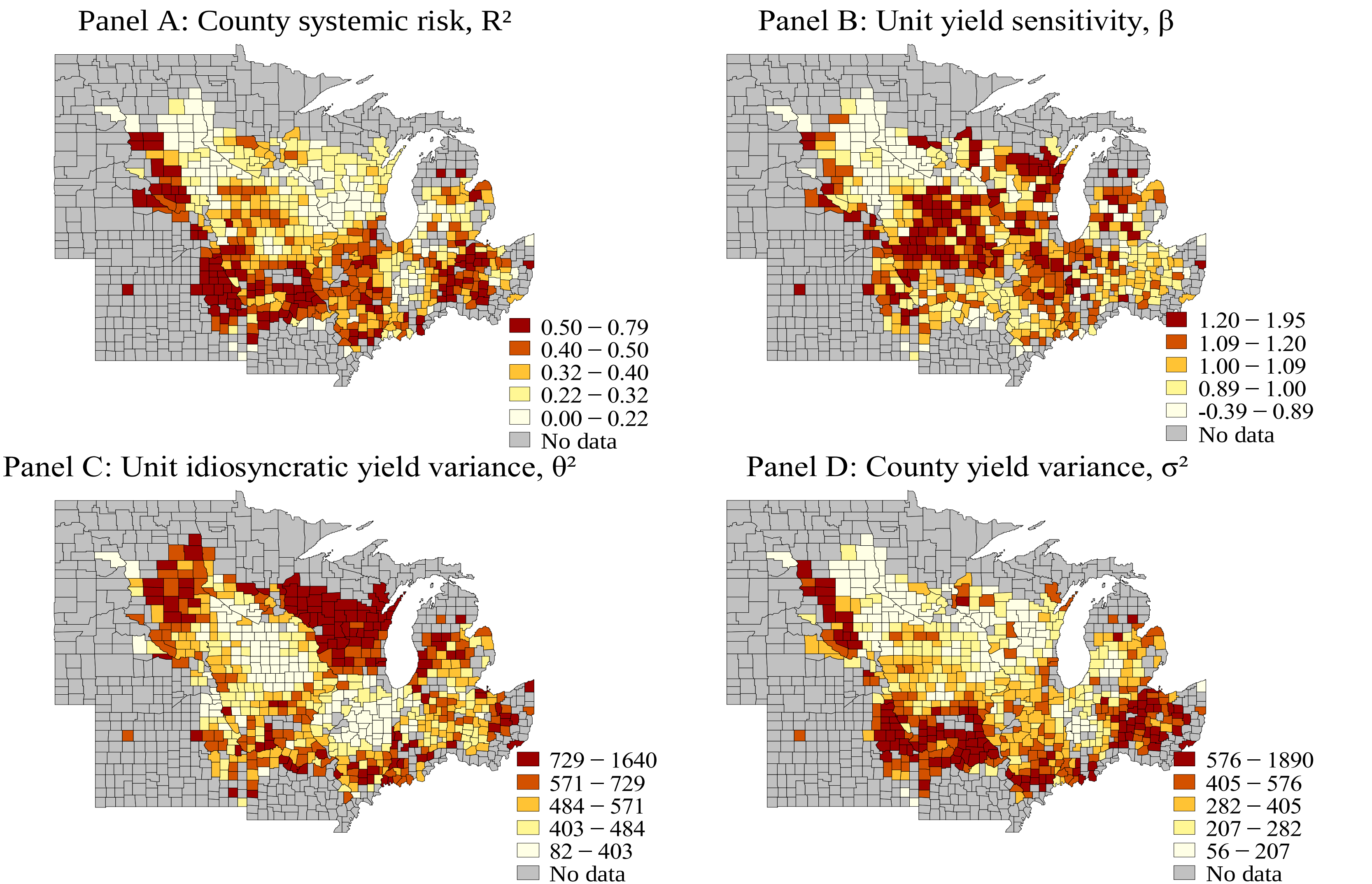

Figure 4. Geographic distribution of county systemic risk and its components

Empirical Results

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$$\ln\left[R_i^2/(1-R_i^2)\right] = \ln\left[\beta_i^2(Z_c)\right] + \ln\left[\sigma_c^2(Z_c)\right] - \ln\left[\theta_i^2(Z_c)\right] \quad (3)$$

Table 2. Effects of county growing conditions on systemic risk

	(1)	(2)	(3)	(4)
	$\ln(\beta_c^2)$	$\ln(\theta_i^2)$	$\ln(\sigma_c^2)$	$\ln[R_c^2/(1-R_c^2)]$
G_c		-	+	
S_c			+	+
P_c	+			+
L_c		-	-	
$Var_t(G_c)$				
$Var_t(S_c)$	-			
$Var_t(P_c)$		-		+

Note: + denotes the coefficient is significantly positive at ≤ 10% level,
- denotes the coefficient is significantly negative at ≤ 10% level.

- **Calibrating TASR**
- By substituting in (1) and indemnity functions of MPCI and ARP into (4), we have

$$\hat{S}_c = \frac{s_i E(\tilde{n}_i)}{E(\tilde{n}_c)} = \frac{s_i \beta_i \int \int_0^{\mathrm{M}_i} F(\tilde{y}_c) d\tilde{y}_c dG(\varepsilon_i)}{\alpha_i \int_{\mathrm{M}_c^{\mathrm{l}}}^{\mathrm{M}_c} F(\tilde{y}_c) d\tilde{y}_c} \quad (6)$$

- Where $F(\tilde{y}_c)$ is the CDF of county yield $\tilde{y}_c$, and $G(\varepsilon_i)$ is the CDF of unit idiosyncratic yield.
  - M_i is the trigger values level of county yield below which MPCI pays strictly positive indemnities.
  - M_c is the trigger values level of county yield below which ARP pays strictly positive indemnities.
  - $\mathrm{M}_c^{\mathrm{l}}$ is the upper bound of county yield below which ARP always pays its maximum indemnity level.

Empirical Results

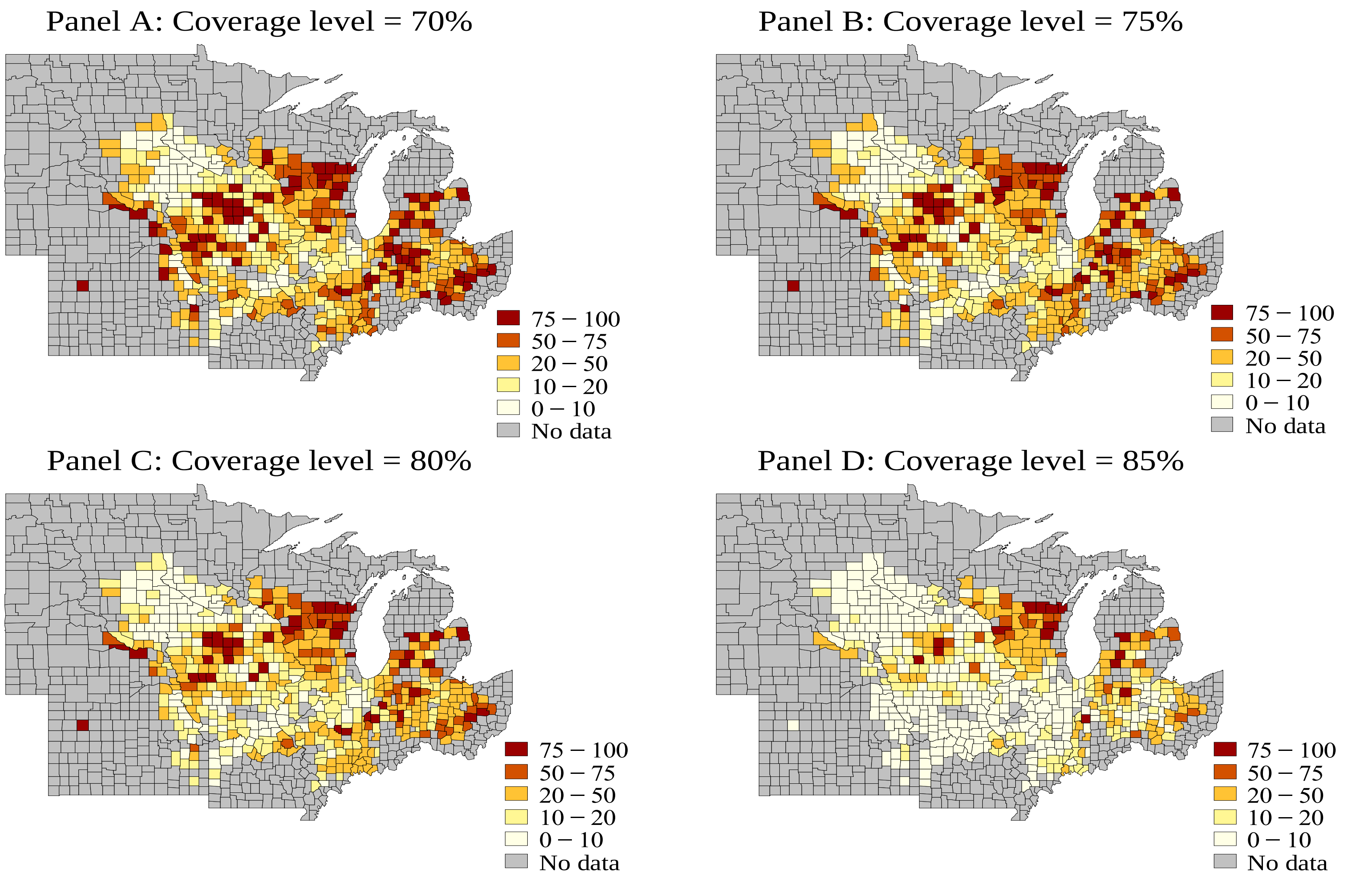

Figure 5. Geographic distribution of the share of units whose TASR is higher than the current ARP subsidy level, %

Conclusion

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- Systemic risk explains about one thirds of individual yield variation, and it varies a lot by counties and is large in Western and Southern Corn Belt.

- The function of risk reduction of area yield insurance should work well in counties with large county yield variance, where the level of excessive heat and precipitation is high and the variability of precipitation is large.

- TASR is negatively correlated with county systemic risk. Area yield insurance is most likely to have a market in some Western and Southern Corn Belt counties where systemic risk is high and TASR is low.

- Even in these counties, many producers will find area yield insurance unprofitable under the current area subsidy rates, especially for those who only want to choose low coverage levels.

- **Identify TASR**
- If no subsidy is offered, i.e., $s_i = s_c = 0$, then ARP and MPCI have the same expected net return, i.e., $E(\tilde{y}_i^{net}) = E(\tilde{y}_c^{net}) = E(\tilde{y}_i)$. Risk averse growers will never choose ARP over MPCI as MPCI provides better risk protection.

- Under actuarially fairness assumption, only when premium subsidies are introduced and the condition $s_c E(\tilde{n}_c) > s_i E(\tilde{n}_i)$ is satisfied, there is a positive probability that risk averse growers will choose ARP over MPCI.

- The subsidy level

$$\hat{s}_c = s_i E(\tilde{n}_i)/E(\tilde{n}_c) \tag{4}$$

then constitutes the lower bond on ARP subsidy rate to attract producers.

- We call $\hat{s}_c$ the threshold area subsidy rate (TASR), below which even risk neutral growers will always choose MPCI over ARP.

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Empirical Results

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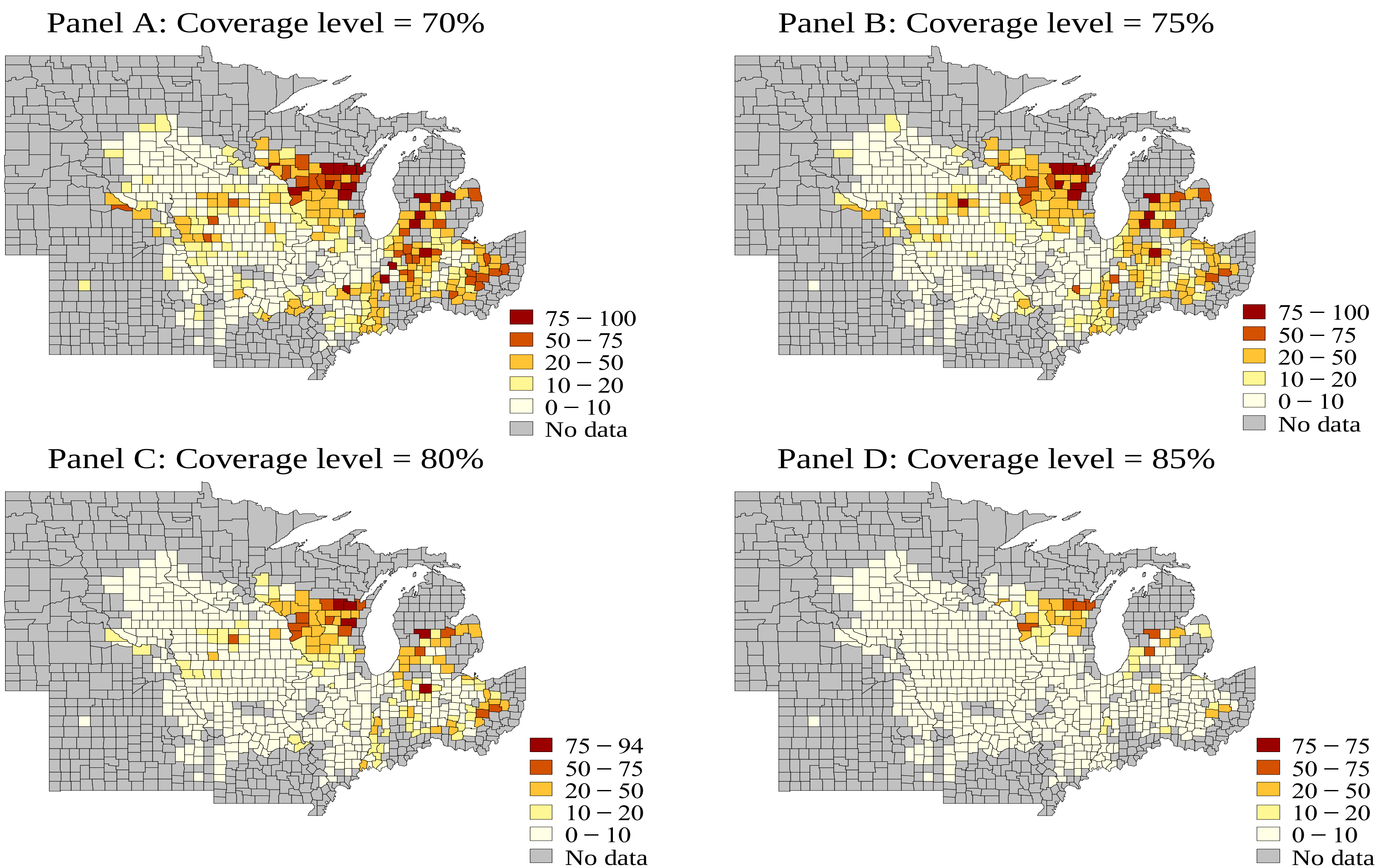

Figure 6. Geographic distribution of the share of units whose TASR is above 100%