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The Effects of Disaster Relief Insurance on Drought Impacts: A Case Study of Southwest Oklahoma*

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Abstract: Many regions in the United States will experience a hotter, drier climate in the coming decades. This prediction is especially troubling for rural communities whose economies depend primarily on agricultural production systems susceptible to drought. The impact of drought on the agricultural sector has knock-on effects on other industries comprising a community's economy. The result is that the total combined losses caused by drought (direct + indirect losses) can exceed direct losses alone. This study quantified the direct and indirect economic losses experienced by five counties in southwestern Oklahoma that experienced exceptional drought at some point from 2000 to 2021. The study also examines how Federal Crop Insurance Program (FCIP) indemnities for corn, cotton, and wheat mitigate the impacts of drought across all economic sectors. Drought caused an average loss of $163 million in output, 1,084 jobs, and $67 million in value-added per drought year in the communities analyzed. However, FCIP crop indemnities reduced drought-caused losses by 54% to 63%. A bumper wheat crop and record-high cattle prices caused by a reduction in supply during drought years also curbed drought-induced losses. These findings suggest that the economies of agricultural communities with more diverse production activities and higher enrollment rates in crop insurance were most resilient to drought.
Keywords: Rural Communities, Multi-Regional Analysis, Insurance Indemnities
JEL Codes: F43, R12, R15

1. INTRODUCTION

Periodic drought is common in southwestern Oklahoma, but drought severity and duration have increased over the last two decades. Climate science predicts that many regions in the United States, including much of southwestern Oklahoma, will experience a hotter, drier climate in the coming decades (Kunkel et al., 2013; Bradford et al., 2020; Pörtner et al.,

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2022)). Much of the central United States periodically experienced "exceptional drought" from 2001 to 2022, including southwestern Oklahoma. The National Oceanic and Atmospheric Administration (NOAA) characterizes exceptional drought as the widespread loss of crops, reduced quantity and quality of forages for livestock, and ground and surface water shortages (NWS, 2024). Severe and frequent droughts have troubled Oklahoma's rural communities because their economies depend on crop and livestock production systems, which are susceptible to water scarcity. Community leaders, water managers, farmers and ranchers, and other stakeholders face the challenges of developing contingency plans for managing water scarcity during critical drought periods. Proactive planning requires understanding the regional economic impact of drought, the vulnerabilities of the community's economic sector, drought resiliency, and the effectiveness of strategies to cope with drought-induced losses.

Drought directly impacts the agricultural sector, indirectly impacts other sectors of a community's economy, and indirectly impacts the economies of neighboring communities. The total economic loss a community experiences due to drought tends to be larger than the direct effect experienced by ranchers and farmers (Kilimani et al., 2018). Total losses exceed direct losses because agricultural production is linked to industries that provide inputs, such as fertilizer, seed suppliers, and loans, as well as output and processing industries, including food processors, cotton gins, and retail businesses. These sectors are affected by drought as demand for agricultural inputs decreases, which in turn disrupts input supplier operations. Further, as the supply of primary agricultural goods decreases, food processors, retailers, and consumers are impacted downstream. Communities may experience additional economic losses due to water use restrictions, loss of outdoor recreational days, burn bans, declines in wildlife populations, and surface water depletion. These indirect and induced losses are essential to consider when measuring the consequences of drought on communities and the potential role of farm safety nets and disaster programs in mitigating drought impacts. However, the broader implications of drought and how crop and livestock insurance can offset those losses have received limited attention.

This research aims to quantify the direct and indirect economic losses caused by drought in five agriculturally dependent counties in southwestern Oklahoma over the past two decades. Using data from the National Agricultural Statistics Service (NASS) and the Farm Service Agency (FSA), we estimated the drought effects on the economic sectors of five counties in Southwestern Oklahoma. We selected 2019 as the base year for modeling because it represents a typical year without extreme wet or dry conditions. The analysis focused on the combined effects of production diversification and the Federal Crop Insurance Program (FCIP net indemnity payments)[1] to determine effective mitigation strategies for the region. The findings offer a longitudinal view of the economic-wide impacts of drought on an agricultural community and the twin role of farm diversification and the FCIP in increasing community resilience.

[1]Since producers owe a premium on the policy purchased, we focus on "net indemnities", or total indemnities minus premium after the premium subsidy has been applied.

2. LITERATURE REVIEW

The U.S. farm safety net combines policies and programs designed to mitigate the damages associated with weather risks. The FCIP, which is part of that safety net along with Agricultural Risk Coverage and Price Loss Coverage programs, and disaster programs, can offset agricultural losses due to drought (Tsiboe and Turner, 2023b). There are FCIP programs for forages and price risks. However, this study focuses on policies available under FCIP that offer risk protection for field crops against weather-related losses.

Like other types of insurance, farmers pay a premium for an insurance policy with specific levels of coverage; however, because of high-risk levels associated with crop production, the federal government partially subsidizes the farmer's premium rate. These subsidies make the insurance product affordable for producers and encourage participation (Coble and Knight, 2002; Glauber, 2013; Bullock and Steinbach, 2023). The FCIP is permanently authorized and frequently updated under farm bill authorizations. Farmers can use a combination of activities and programs to manage risk, including the FCIP, new technologies or seed varieties, vertical integration, and enterprise diversification.

In the United States (U.S.), producers employ various strategies to manage the impact of natural disasters; however, they prefer crop insurance (Falco et al., 2014; Tsiboe and Turner, 2023b). Federal efforts to offer producers a safety net to rebound from natural disasters emerged in the 1930s. Crop insurance was introduced in 1938 to offset the Dust Bowl's effects on farms and rural economies. However, FCIP participation was low until Congress passed the 1994 Federal Crop Insurance Reform Act, eventually forming the Risk Management Agency in 1996. The bill also introduced catastrophic coverage (CAT), which covers a 50% loss in revenue or yield and is free to producers, a policy still in place today (Glauber, 2013).

After 1996, participation increased dramatically, with up to 80% of selected crop acres covered in the late 1990s and up to 90% covered in 2020 (Tsiboe and Turner, 2023a). Crop producers can choose to enroll in several types of programs, with the two main options selected in this region being revenue protection and yield loss protection. Revenue protection and yield loss protection guard producers against losses due to natural disasters, including drought, excessive moisture, wind, insects, and disease. Revenue protection is most commonly purchased. It provides protection against yield losses and price changes. The increase in enrollment in and indemnities from FCIP has steadily climbed since the early 2000s, which is consistent with trends of climate volatility (Pörtner et al., 2022; Tsiboe and Turner, 2023a). Other studies found that the FCIP mitigates the negative financial impacts on farm income caused by natural disasters (Stone, 2014; Wilhite et al., 2014; Wilhite, 2017). Producers in the U.S. received over $10 billion in FCIP net indemnities to cover losses from the 2012 drought (Prager et al., 2017). While other studies have examined the efficiency of FCIP in managing farm-level risk, few studies have considered how insurance offsets the indirect losses of drought in agriculture-dependent communities.

Previous research on analyzing drought impacts focused on where and when drought occurred using water availability measurements (Wilhite et al., 2007), the impacts on human and community health and well-being, such as increasing incidences of mood disorders and suicide (Vins et al., 2015; Yazd et al., 2020), and spatial and temporal crop yield reduction

(Kuwayama et al., 2019). Only a few studies have investigated the economy-wide impacts of drought in agriculturally dependent areas where most households and businesses depend on farm income.

Arndt (2002) quantified the direct effects of drought on the agricultural, transportation, and retail sectors in Oklahoma. The study estimated a loss between $3 billion to $5 billion in agricultural products caused by Oklahoma's 2000 to 2001 drought. However, the analysis by Arndt (2002) did not consider the forward and backward linkages of the agricultural sector to the rest of the state's economy. Bauman et al. (2013) used input-output procedures and an equilibrium displacement model to estimate the impacts of drought in 2011 on Colorado's economy. They found that losses ranged between $83 and $100 million across 17 counties in Colorado. Wittwer and Griffith (2011) estimated a loss of 6,000 jobs in Australia's southern Murray-Darling basin region's economy due to drought from 2006 to 2009. Drought-impact research also tends to exclude the livestock sector (Bauman et al., 2013). However, managing livestock in addition to crops sometimes buffers crop losses (Fafchamps et al., 1998; Kinsey et al., 1998). Therefore, the effect of livestock on drought conditions is important if cattle are a major regional agricultural commodity.

A few studies included the impact of disaster relief programs on economy-wide impact analyses. Wittwer and Griffith (2011) extended their analysis to benchmark a water buy-back policy. Farmers' reduced water availability through government water buy-backs moderated losses. Research on FCIP concerning drought or other weather-related disasters focused on how this insurance may impact producers' production choices (Glauber et al., 2002; Falco et al., 2014) and the amount paid by the government in insurance or disaster programs following drought events (Glauber et al., 2002; Janda, 2015). However, research on how these payments affect economic industries over time is lacking, especially concerning drought in the last two decades.

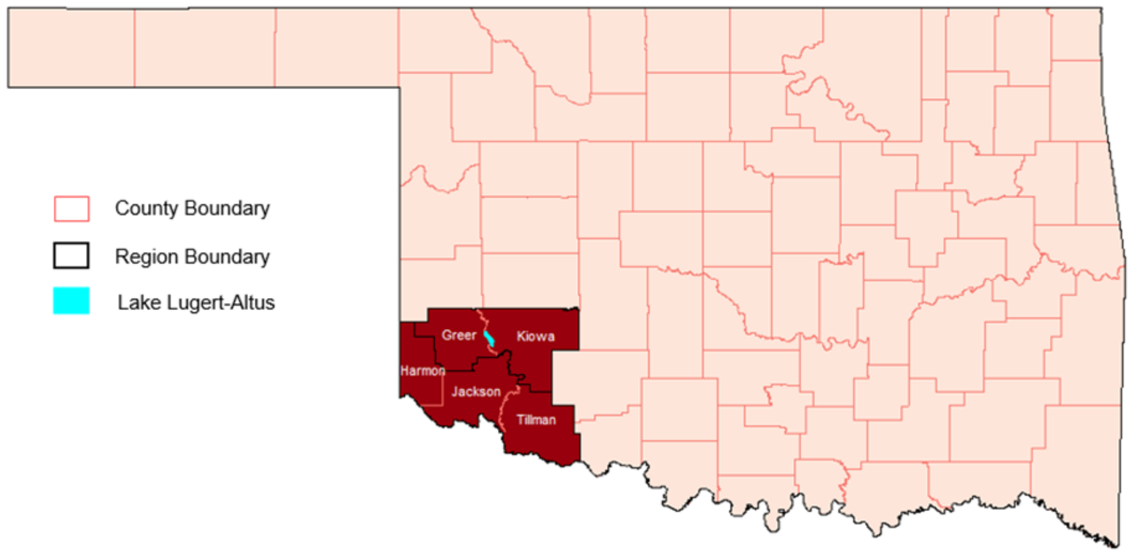
This study contributes to the existing literature by providing a detailed case study that quantifies the combined mitigation effects of production diversification and FCIP net indemnity. Our analysis provides a more comprehensive perspective on drought's economic impact by analyzing the two strategies together over the last two decades. The study fills a gap in the literature by showing that applying both strategies can be more effective in sustaining agricultural productivity and economic stability in the face of increasingly frequent and severe droughts.

3. STUDY REGION

This research focused on five drought-impacted counties in southwest Oklahoma: Harmon, Jackson, Tillman, Kiowa, and Greer (Figure 1). Harmon, Jackson, and Tillman counties are aggregated to form an economic region (R-HJT, hereafter) that was most severely impacted by drought events. In contrast, Kiowa and Greer were aggregated to form an economic region (R-KG, hereafter), which mostly suffered indirect impacts due to the drought in R-HJT (Figure 1). The remaining Oklahoma counties are combined into a third economic region (ROOK, hereafter).

Region R-HJT is the region of interest in this study, as are the direct effects of drought

Figure 1: Study Region



on those counties. The 3-county region has a total population of 34,241 (USCB, 2022a,b,c). The median household income ranges from $46,306 in Tillman County to $60,954 in Jackson County (USCB, 2022a,b,c). According to the Economic Research Service (Pender, 2019), Tillman and Harmon counties are agriculture-dependent, meaning that more than 25% of employment is associated with agriculture. Jackson County, which houses a military base and a small college in Altus, is less agriculture-dependent but still includes many agriculture-dependent households outside of Altus. Agriculture employs the most workers, with 2,329 producers in the combined area, most of which operate family farms. Some farms in the region hire off-farm workers, employing 25% of the civilian working population in Harmon, 6.3% in Jackson, and 10% in Tillman County. R-HJT had a total of 786 business establishments in 2022, with the major employers being education services, healthcare, and social assistance, as well as other employing industries, including manufacturing, retail, and public administration (USCB, 2022a,b,c).

Region R-HJT is a center of significant agricultural activity in Oklahoma, contributing about 5% of the state's agricultural sales in 2017 (NASS, 2019a,b,c). The primary commodities produced in this region are cotton, wheat, hay, corn, sorghum (grain and forage), canola, and beef cattle. The number, size, and distribution of farms follow national trends, with a decrease of 25% in the total number of farms in the region and an increase of 40% in the average size of the farms from 2012 to 2017 (NASS, 2019a,b,c). Production activities in R-HJT fluctuated over the study period, generally trending regarding water availability (Table 1). All crops experienced lower yields and fewer planted acres during prolonged droughts, such as the extended drought of 2011 to 2014. The 2013 wheat yield was only 16 bushels per acre, with the 20-year average at 27 bushels per acre. There were 4,000 acres of corn planted (an average of 9,000 acres) and 117 thousand acres of cotton planted (an average of 191 thousand acres). Cattle herds were also impacted, with 2013 having the smallest cattle

Table 1: Acres Planted and Yield in Harmon, Jackson, and Tillman County from 2000-2001

	Wheat		Corn		Sorghum		Cotton		Cattle
Year	Acres Planted (000 acres)	Yield (bushels per acre)	Acres Planted (000 acres)	Yield (bushels per acre)	Acres Planted (000 acres)	Yield (bushels per acre)	Acres Planted (000 acres)	Yield (bushels per acre)	Head (thousand head)
2000	460	33	10	78	50	98	188	588	32
2001	340	29	13	40	55	131	193	564	32
2002	465	27	12	79	22	106	131	633	32
2003	525	28	12	82	21	110	122	701	39
2004	500	32	15	85	14	137	152	877	34
2005	450	31	11	69	8	125	169	851	32
2006	440	22	9	50	4	41	208	620	35
2007	485	33	15	103	23	157	120	946	32
2008	423	39	-	79	12	46	56	1098	29
2009	602	14	7	77	-	-	139	989	29
2010	508	29	13	83	-	-	178	971	29
2011	415	17	3	79	-	-	225	596	29
2012	485	30	3	93	2	23	150	685	23
2013	478	16	4	83	-	-	117	872	21
2014	541	13	2	83	-	-	158	499	22
2015	512	22	6	83	24	74	143	894	23
2016	449	30	13	52	-	-	199	1088	24
2017	389	28	6	52	3	55	319	1022	26
2018	342	23	5	52	-	-	374	762	44
2019	411	33	7	52	5	111	312	787	45
2020	533	26	14	40	2	25	276	840	44
2021	363	34	14	68	8	49	274	753	46

Notes: Data presented in this table are from National Agricultural Statistic Service (NASS). Missing data "-" means the data either was not collected or there was not sufficient production in the region.

herd in the study period at 13,000 head. Alternatively, there were years when precipitation was plentiful, and yields were higher than average. For example, in 2007, corn yields were 103 bushels per acre compared to an average of 71 bushels per acre, and cotton yielded 946 lbs per acre compared to an average of 802 lbs per acre.

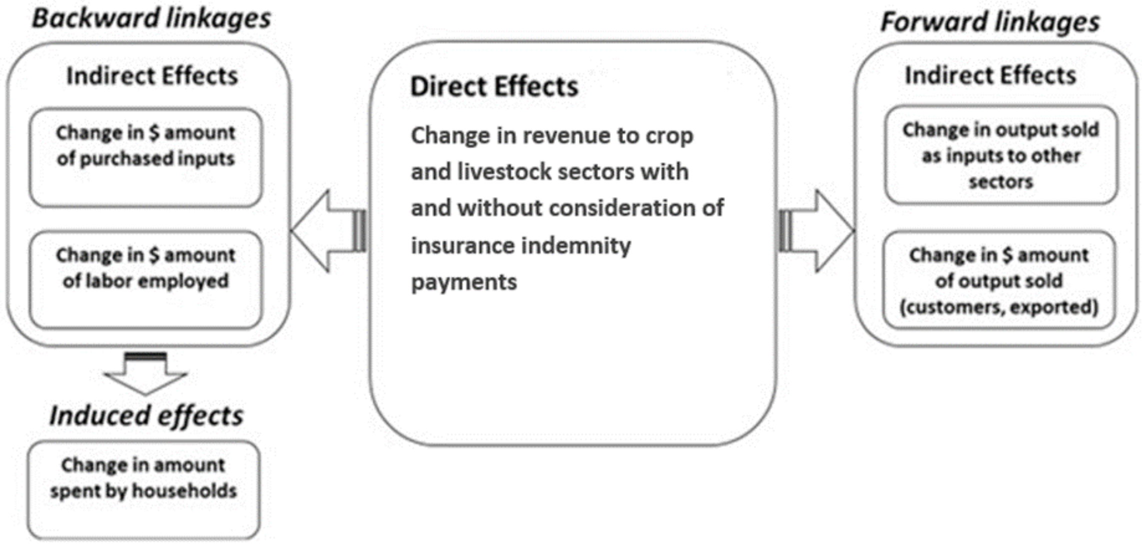
Groundwater is the primary water source for crop irrigation, and crop irrigation is the main contributor to groundwater depletion (Boyer et al., 2017). R-HJT withdraws water from two principal aquifers: the Blaine and the Tillman Terrace aquifers (OWRB, 2023). In addition to these two aquifers, irrigators withdraw surface water from the Tom Steed Reservoir in Kiowa County and Lake Altus-Lugert on the boundary of Greer and Kiowa Counties (Figure 1). Therefore, the economic region R-KG (encompassing Kiowa and Greer counties) is indirectly affected by R-HJT's drought event due to R-KG supplying surface water, among other agricultural inputs, to R-HJT.

4. METHODS AND DATA

4.1. Multi-Regional Input-Output (MRIO) Model

A multi-regional input-output (MRIO) model was developed using the IMPLAN modeling system (IMPLAN, 2021) to quantify drought-induced loss and indemnities on jobs, total industry output (TIO), and total value-added (TVA) in the three economics regions mentioned in section 2: R-HJT, R-KG, and ROOK. MRIO models are used to model interdependencies between industries and the exchange of goods and services with industries in other regions through market-based transactions. TIO measures the annual dollar value of an industry's goods and services. Employment includes full- and part-time wages and salaries for employees and the self-employed. TVA captures employee compensation, proprietary income, other property income, and tax on production and imports. These effects are captured by the

Figure 2: Flows of direct, indirect, and induced effects.



interindustry transactional linkages (Figure 2). MRIO analysis is based on Leontief's single region Input-Output model (Leontief, 1936, 1951). A single region input-output model captures direct, indirect, and induced effects in a region's economy. However, any effects that leave the region are leakages. A leakage is any money that exits the model's region. MRIO models recover leakages that occur otherwise in single-region input-output models (Miller and Blair, 2009).

The 547-industry definition used by IMPLAN was aggregated into 22 industries (Appendix A). The aggregation reflects the main productive activities of regions R-HJT and R-KG's economy, including cotton, grain, livestock, and Financial, Insurance, and Real Estate industries (FIRE). Agricultural industries in this region contribute \$518 million in output, 2,820 jobs, and \$175 in TIO for the base year 2019 (author's calculations). Figure 2 shows how changes in revenue from crop and livestock production affect input purchases and output sold through backward and forward linkages.

Negative shocks, such as severe drought, cause direct, indirect, and induced losses. Agricultural industries experience direct effects, such as a loss in revenue due to changes in yield and harvested acres in crop industries and the change and value of herd size in livestock industries. Indirect effects propagate through upstream and downstream industry linkages. As an example of a backward linkage, farmers may abandon a crop during severe drought, decreasing demand for custom harvesting.

Regarding forward linkages, a decrease in grain production means processors and millers will pay higher prices due to commodity shortages, decreasing food processors' and millers' TIO. The industries with the highest indirect impacts from agricultural production in this region include FIRE, agriculture inputs, wholesale trade, retail trade, and services. Consequently, these industries will likely be most impacted by indirect impacts caused by drought.

Induced effects include decreased household spending as employee compensation decreases due to fewer work hours in affected industries. The MRIO model captures all direct, indirect, and induced effects across all sectors in the model until all the impact effects have leaked from the region.

4.2. Potential Revenue Loss from Crop and Livestock Production

Wheat, corn, alfalfa hay, cotton, and sorghum are the main crops affected by drought in the R-HJT region. Crop and livestock revenue losses due to drought events are calculated as differences in reported revenue. The potential revenue is the revenue the producer would have earned absent drought (Bauman et al., 2013). For each county and crop commodity, we calculated potential revenue for each year (t) from 2000 to 2021 as Equation 1:

$$PR_t = A_t \times H_t^{OMA5} \times Y_t^{OMA5} \times P_t \quad (1)$$

where PR is potential revenue, A is planted acres, H_t^{OMA5} is the 5-year Olympic moving average of the crop harvest rate for planted acres, Y_t^{OMA5} is the 5-year Olympic moving average of crop yield, and P is the crop commodity price. The Olympic average was used because it is the procedure used by the United States Department of Agriculture (USDA) to calculate yield-based payments.

The actual revenue is the revenue received by producers in year t (Equation 2):

$$AR_t = HA_t \times Y_t \times P_t \quad (2)$$

where AR is the actual revenue received, HA is harvested acres, Y is realized yield, and P is the commodity price. Direct losses due to drought from each crop production at the county level are calculated as the difference between PR and AR.

The USDA National Agricultural Statistic Service (NASS) county-level data on planted and harvested acres and yield levels from 1995 to 2021 was used to calculate H_t^{OMA5} and Y_t^{OMA5} . However, USDA-NASS does not have complete records for harvested corn acres. We used the Cropland Data Layer (CDL) and the Cropscape R package by Chen (2020) to calculate the missing harvested corn acres. The CDL is a snapshot of crop cover collected via satellite imagery during the growing season across the United States. Corn acreage derived from the CDL is used to proxy harvested corn acres. Crop commodity prices received from 2000-2021 were also from USDA-NASS.

Potential crop commodity revenue losses due to drought were calculated at the county level for four main crops (wheat, corn, alfalfa hay, and cotton) in the R-HJT drought. These direct losses were distributed over the Grain, Cotton, and other agricultural activities (Other Ag) sectors as direct impacts on revenue. Revenue losses in wheat and corn were distributed to the Grain sector, cotton to the Cotton sector, and alfalfa to the Other Ag sector. The potential revenue losses proxy the changes in revenue during drought years, in addition to years with adequate water availability. Negative returns occur during drought years, while years with adequate moisture produce positive returns.

Calculations of the impacts of drought on the cattle sector are less straightforward than those for crops. Livestock producers keep some cattle as breeding stock from one year to the next, making their valuation more like an asset than a single-year commodity. Additionally, livestock impacts can be delayed because regional producers would rather postpone culling cattle to preserve their herd's genetic integrity. Finally, which cattle are sold and retained affects the total value of the herd because individual cattle value depends on breed, sex, age, grade, and other characteristics.

We used the value of the change in livestock inventory obtained from the Bureau of Economic Analysis farm income and expenses table CAINC45 (BEA, 2022). The total livestock value of inventory change is reported as the change from the previous year in dollars. This change in value includes anything that affected the dollar value of the herd, including changes in the herd composition, total numbers, and market prices for each year.

Table 2 presents the potential revenue loss values from 2000 to 2021 by sectors for the R-HJT economic region. Positive values in Table 2 indicate no economic loss to the sector in those years. All three crop sectors (Grain, Cotton, and Other Ag) had negative direct impacts, as expected in drought years when the potential revenue was greater than the actual revenue. In 2012, the Grain sector experienced a positive impact on revenue even during the drought year. The positive return happened mainly due to a bumper wheat crop (Palmer, 2012). The calculations from Table 2 exhibit a loss to the cotton sector in R-HJT in 2019. However, these were isolated regional effects of drought, and most of the state was not experiencing drought during that period. Livestock inventory values are positive for 2013 through 2018 (Table 2). The USDA's January cattle report estimated Oklahoma's cattle herd at 4.2 million head in 2013, a decrease of 300 thousand head from 2012, and the national cattle herd was the smallest on record since 1952. Positive inventory values were likely a result of increased prices due to the decreased supply following the cattle cull.

4.3. Indemnity Payments

Table 3 presents the FCIP net indemnity payments received by R-HJT for wheat, corn, and cotton from 2000 to 2021. The annual net indemnity payments from crop losses are from the Risk Management Agency (RMA) location and crop-specific Cause of Loss dataset. This data allows us to isolate net indemnities for crop losses occurring due to drought, excluding all other causes of loss. The three counties in the R-JHK region received an average of $18.9 million in annual net indemnity payments over these two decades. The annual wheat and cotton net indemnity payment is, on average, $9.3 million and $9.5 million, respectively. Corn net indemnity payments averaged $61,000 annually, and indemnities were only paid in 14 of the 21 years, meaning drought significantly damaged crops in more than half of the study years. Indemnities were considerably higher in years with widespread drought events (i.e., 2000-2002, 2006, 2009, 2011-2014, and 2018-2021) than in other years. FCIP damages are assessed at the field level, meaning that soil type, location, and topography can affect localized drought damages.

For this reason, indemnities associated with drought as a cause of loss may still be observed in years in which other parts of the county were not experiencing a widespread drought. During widespread drought years, there was an average indemnity amount of $15.6 million for wheat, $86,000 for corn, and $17.1 million for cotton. There were, in total, $32.8 million in net indemnity payments across these three crops.

Table 2: Estimated Revenue Losses for R-HJT ($ millions)

Year	Grain	Cotton	Other Ag	Livestock
2000	-6.12	-7.40	0.00	-2.26
2001	-9.31	-0.23	0.00	2.64
2002	-6.63	10.91	0.00	3.37
2003	0.85	20.14	0.00	-4.86
2004	10.31	23.85	0.00	3.98
2005	2.32	21.83	0.00	1.65
2006	-26.81	-35.04	0.00	-3.03
2007	30.91	18.40	0.00	3.13
2008	34.16	5.97	0.00	0.00
2009	-60.89	10.07	0.62	1.82
2010	6.28	9.81	-0.62	-5.89
2011	-26.68	-160.49	-6.52	-16.79
2012	25.34	-89.76	-3.70	-7.68
2013	-48.84	-51.46	-0.04	2.77
2014	-26.79	-15.66	-0.22	10.45
2015	11.08	30.89	1.05	9.34
2016	7.25	77.37	1.30	6.24
2017	-2.09	69.37	-0.05	2.79
2018	-15.59	-118.44	-2.29	5.29
2019	6.21	-55.88	0.23	-3.77
2020	-17.71	-14.88	0.97	3.34
2021	13.98	-12.63	0.00	-2.62

Notes: All values are in 2023 dollars.

Table 3: Indemnity Payments by Crop Commodity in R-HJT ($ thousands)

Year	Wheat	Corn	Cotton
2000	3234	75	3907
2001	177	150	6512
2002	4742	50	356
2003	2568	20	294
2004	2857	44	90
2005	508	35	107
2006	16327	115	9572
2007	25	0	1
2008	2384	146	596
2009	43625	8	728
2010	459	22	240
2011	26164	0	31868
2012	7429	0	59322
2013	40816	4	13706
2014	38020	0	1050
2015	3717	0	103
2016	708	0	51
2017	834	0	1713
2018	9933	238	44330
2019	185	31	21972
2020	433	311	8918
2021	773	95	3349
Average	9360	61	9490
Drought Average	15593	86	17103

Notes: Rows shaded in grey are drought years. "Drought Average" is the average over the drought years.

4.4. Impacts Due to Drought

The impact analysis determines, for each industry, the economic losses or gains caused by a potential loss in revenue from crop and livestock production due to drought. We use the 2019 input-output tables from IMPLAN as the baseline for the 2001 to 2021 study period. Using a drought year or a year with high precipitation would not be an ideal benchmark. Crop production in 2019 was at similar levels to the average over the study period regarding acres planted and yield, making it a suitable baseline (Table 1). If a drought year were used as the baseline, the effects of the drought would already be reflected in the IO tables.

Regardless, assuming a constant production function has limitations. Using 2019 as the reference year, we implicitly assume that the underlying economic structure, technology, and sectoral relationships (i.e., how industries produce goods and services) remain unchanged from 2011 to 2021. Our assumption overlooks potential structural shifts in the local economy, such as the expansion or contraction of specific sectors or changes in energy use. Agriculture might shift to less water-intensive practices in response to prolonged drought. This shift would likely take longer for irrigated agriculture, the dominant practice in the stay area. However, the constant production function assumption would miss these adaptations.

Therefore, the impact estimates may be overstated or understated if there have been significant changes in technology, input prices, productivity, or industry composition between 2001 and 2021. Negative impacts would be overstated if the agricultural sector and closely related industries adapted to drought by increasing efficiency or diversifying input use. Conversely, the negative impacts of drought would be understated if industries become more vulnerable due to reduced investment, labor shortages, or supply chain dependencies because of the assumption that industries are operating at 2019 efficiency levels over the study period. We need IO tables spanning 2011 to 2021 to address this limitation as a robustness check. These caveats should be carefully considered when interpreting the results.

The ex-ante effect of FCIP net indemnity payments on offsetting direct, indirect, and induced losses is also evaluated. We conducted the impact analysis under two revenue change scenarios. The first scenario (LP) estimates the impact of potential revenue loss from crop and livestock production in the drought directly impacted region R-HJT, absent protection from the purchase of an FCIP policy. The second scenario, LP + Indemnity, offsets drought-induced losses by including indemnity payments in the actual revenue received by the R-HJT region. The gap between actual and potential revenue will narrow with the addition of the indemnity payment. The question remains: How does FCIP support the crop and livestock sectors in buffering losses in supporting sectors regarding total industry output, value-added, and jobs?

5. RESULTS

5.1. Drought Impact on the State Economy

Table 4 presents the state-level TIO, employment, and TVA changes under the PL and PL+Indemnity scenarios from 2000 to 2021. The study includes five notable widespread drought periods: 2000 - 2001, 2006, 2009, 2011- 2014, and 2018 - 2021. Among these periods

Table 4: Economic Impact on Oklahoma's Total Industry Output (TIO), Employment, and Total Value-Added (TVA)

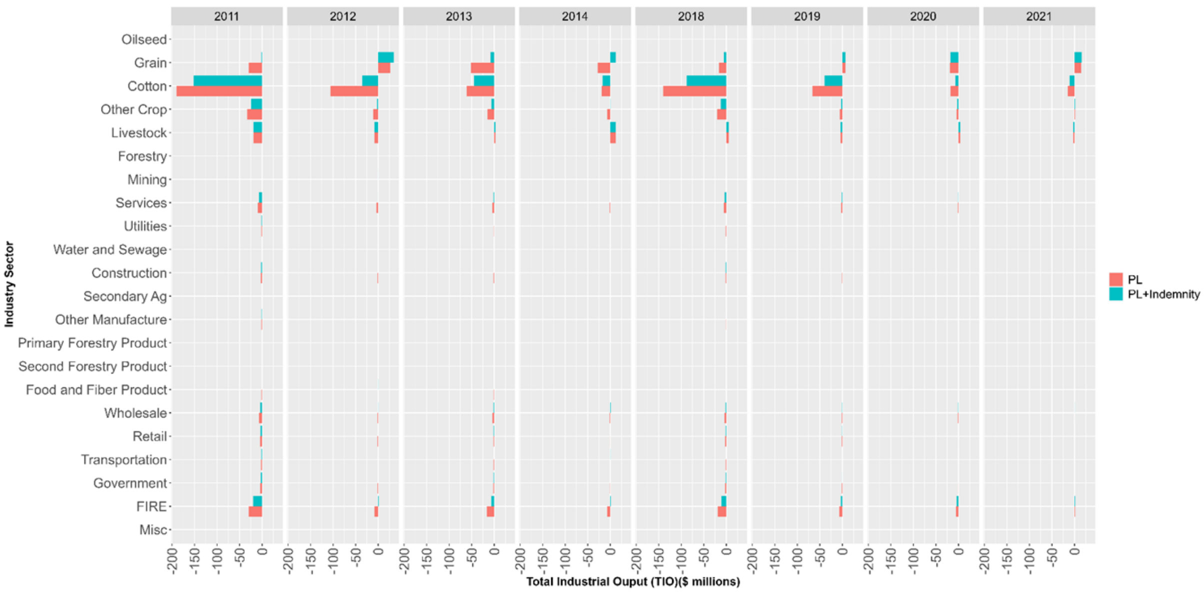
Year	TIO ($ millions)		Employment (jobs)		TVA ($ millions)	
	PL	PL + Indemnity	PL	PL + Indemnity	PL	PL + Indemnity
2000	-25.15	-13.51	-158.55	-84.51	-9.05	-4.82
2001	-11.73	-0.83	-73.22	2.15	-2.90	1.91
2002	11.48	19.90	76.15	128.18	6.60	8.92
2003	26.27	30.98	175.67	204.83	12.43	13.76
2004	60.75	65.65	387.09	417.28	23.49	24.81
2005	41.00	42.06	265.11	271.69	17.46	17.77
2006	-104.19	-62.00	-661.56	-396.12	-38.16	-24.21
2007	84.56	84.61	530.55	530.82	28.05	28.06
2008	65.49	70.59	406.64	438.36	19.02	20.54
2009	-80.22	-7.55	-477.74	-30.16	-17.59	1.76
2010	16.37	17.54	98.46	105.8	6.31	6.68
2011	-332.89	-239.28	-2249.52	-1653.94	-140.74	-106.60
2012	-117.76	-11.15	-838.67	-146.22	-60.56	-14.83
2013	-157.94	-69.22	-1005.1	-450.79	-56.66	-29.22
2014	-53.71	10.27	-347.32	47.00	-17.90	-0.74
2015	82.55	88.81	541.11	579.67	32.44	34.11
2016	146.05	147.29	965.65	973.32	63.85	64.20
2017	111.05	115.14	724.12	750.36	50.14	51.73
2018	-209.40	-122.55	-1401.14	-839.52	-91.16	-55.10
2019	-84.04	-48.76	-546.27	-315.68	-39.01	-23.18
2020	-46.45	-31.54	-279.87	-182.67	-15.78	-9.20
2021	-1.05	5.54	-13.28	29.37	-4.29	-1.56

Notes: Rows shaded in grey are drought years.

and the under PL scenario, Oklahoma lost, on average, over $102.04 million in TIO, 671 jobs, and $41.15 million in TVA during the drought years (Table 4). These losses were reduced by 50%, on average, after compensating losses in revenue with FCIP indemnity payments (PL + Indemnity), with an average loss over drought years of $49.22 million in TIO, 335 jobs, and $22.15 million in TVA.

FCIP net indemnity payments mitigate the effects of drought on local and regional economies. In years characterized by no drought or isolated drought, such as 2002-2005, 2007-2008, 2010, and 2015-2017, the TIO, employment, and TVA are similar under the PL and PL + Indemnity scenarios. However, in years when widespread drought occurred, there are significant differences in TIO, employment, and TVA (Table 4). The most severe drought period was from 2011 to 2014. The average yearly loss during this period was $165.58 million in TIO, 1,110 jobs, and $68.97 million in TVA. There was a much higher loss in 2011 because the drought-related loss was larger than the net indemnity received. In 2011, with the FCIP indemnity payment in force, the TIO loss was only reduced by 28% in 2011, compared to 91% in 2012, 56% in 2013, and 119% in 2014. The bumper wheat crop in 2012 and record high cattle prices in 2013 and 2014 also reduced the combined economic losses from drought.

Figure 3: Impacts on Total Industry Output (TIO) by industry in drought years. PL: potential revenue loss from crop and livestock production; PL+Indemnity: potential revenue loss from crop and livestock production with indemnity payments.



Drought, directly and indirectly, affected all 22 industries. Figures 3-5 present TIO, employment, and TVA changes for selective drought years where exceptional drought covered most of the 3-county area, including 2011-2014 and 2018-2021. The losses in the Cotton, Grain, Other Ag, and Livestock sectors were caused by direct impacts (losses in potential revenue) and additional losses accrued through indirect and induced effects. All other industries experience indirect or induced impacts through their linkages with the Cotton, Grain, Other Ag, and Livestock sectors.

The most affected sectors are Cotton, Grain, Other Ag, Livestock, and FIRE (Figures 3-5). During the multi-year exceptional drought period of 2011 to 2014, enterprises experienced the greatest losses in 2011. However, the losses were moderated in the subsequent years under the PL and PL+Indemnity scenarios. This loss reduction may be attributed to 1) producers anticipating the likelihood of multi-year droughts and adopting more conservative practices over successive years, 2) the drought becoming less severe after 2011, or 3) a combination of both factors.

Indemnity payments offset some of the negative returns to agriculture caused by drought. In some cases, FCIP indemnity payments were enough to eliminate losses, thus producing positive TIO in the directly impacted sectors such as grain farming in 2011 and 2014. The indemnity payments scenario also buffered losses to the extent that the economic indicators were positive during less widespread drought years. The FIRE, transportation, and services sectors in 2012 are examples of indemnity payments offsetting losses in sectors closely related to agriculture (Figures 3-5). The significance of this finding is that there is evidence of FCIP indemnity payments transferring a sector from one of the least resilient (experiencing the

Figure 4: Impact on employment (jobs) by industry sectors in drought years. PL: potential revenue loss from crop and livestock production; PL+Indemnity: potential revenue loss from crop and livestock production with indemnity payments.

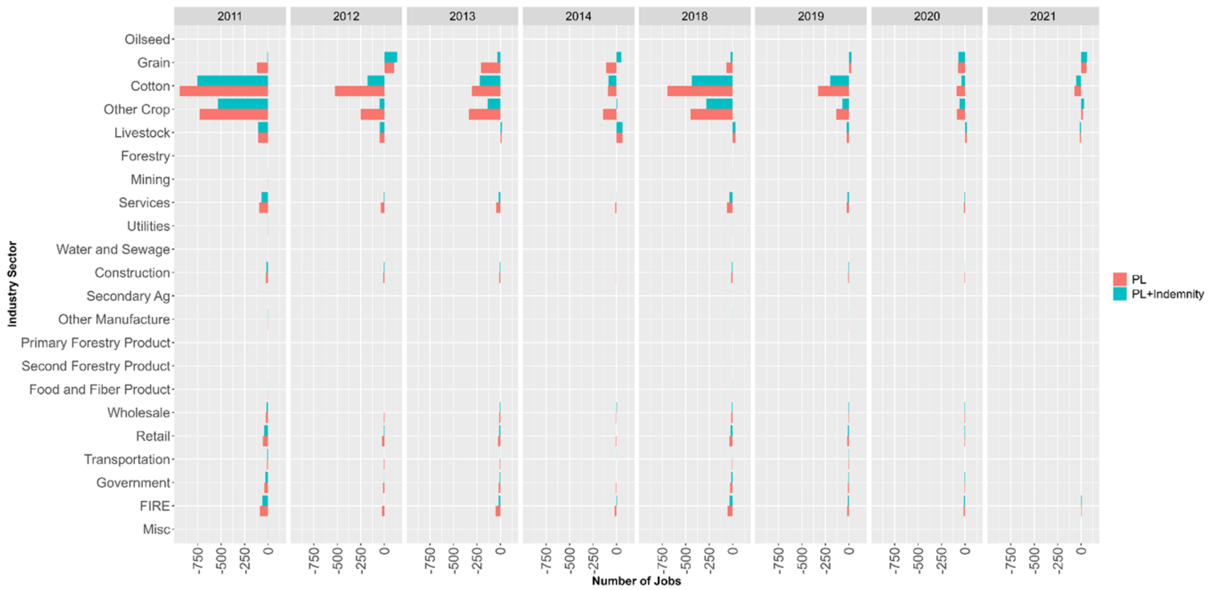


Figure 5: Impacts on Total Value-Added (TVA) by industry in drought years. PL: potential revenue loss from crop and livestock production; PL+Indemnity: potential revenue loss from crop and livestock production with indemnity payments.

most significant effects from drought) to one of the most resilient (experiencing minor effects from drought). Cotton was one of the most severely impacted industries, as it heavily depends on irrigation, which became more limited as the severe drought continued. Indemnity payments reduced the negative impacts of drought on returns to cotton but not enough to generate positive impacts.

Tables 5-6 summarize the impact on Oklahoma employee compensation by income groups under the PL and PL + Indemnity scenarios. Under the PL scenario, employee compensations are induced impacts based on changes in working hours for the impacted industries (Table 5). When this impact is distributed across income groups, households making \$20K to \$40K a year are disproportionately impacted, losing an average of \$9.67 million in drought years, followed by the \$40K to \$60K group (-\$2.09 million), the \$60K to \$80K households (-\$1.36 million), the \$80 to \$100K group (-\$1.27 million) and the greater than \$100K households (-\$0.71 million). Notably, the households earning less than \$20 thousand a year experienced the most minor yearly losses. In Oklahoma, those employed in the less than \$20 thousand a year income group were fishing and hunting workers. These sectors were relatively unaffected by drought. Considering the effects of loss in the \$20K to \$40K income households, the occupations in this group comprised workers employed by the crop and livestock sectors, personal health, forestry, and other service sectors. These industries were most affected by drought. Under the PL + Indemnity scenario, the negative employee compensation impact during drought years, especially in 2011 and 2018, was moderated (Table 6).

5.2. Drought Impacts on the Regional Economy

The R-HJT region experienced the highest losses because it was most severely impacted by drought. The average effects over the years of widespread drought included \$103.55 million in TIO, which was reduced by 50% to \$52.89 million after considering FCIP indemnities (Table 7). Compared with the R-HJT counties, the R-KG and ROOK regions experienced much smaller losses, except for 2011, when the drought was severe across the state's western half. Although the R-KG group is closer to the direct impact region R-HJT, the ROOK region is larger, and has relatively larger impacts compared to region R-KG. Under the PL + Indemnity scenario, R-HJT benefits from receiving indemnity payments, resulting in less loss in TIO, employment, and TVA (Tables 7-9). In 2014 and 2021, R-HJT experienced a positive impact on TIO and employment after including indemnity payments.

6. CONCLUSIONS

The purpose of this study was to quantify the economy-wide effects of the direct impacts of drought in a three-county agricultural region in Southwestern Oklahoma due to losses in the crop and livestock sectors, as well as the indirect impacts to the neighboring regions that supply water an agricultural inputs to the target counties. Weather-related disasters are one of the factors attributed to the national decline in the number of farms, which results in increased individual risk to remaining farms as they share a more significant portion of the market. Thus, these estimates of drought and disaster-relief policies are vital information

Table 5: Impact on Oklahoma Employee Compensation by Income Group under Potential Loss from Crop and Livestock Production and Indemnity (PL+Indemnity)($ millions)

Year	Income Group					
	<$20K	$20K-$40K	$40K-$60K	$60K-$80K	$80K-$100K	>$100K
2000	0	-1.86	-0.66	-0.32	-0.26	-0.17
2001	0	-0.72	-0.66	-0.18	-0.11	-0.10
2002	0	1.47	-0.27	0.13	0.18	0.06
2003	0	3.43	0.44	0.37	0.43	0.19
2004	0	5.12	1.05	0.79	0.69	0.40
2005	0	4.05	1.74	0.53	0.53	0.27
2006	0	-8.39	1.31	-1.38	-1.15	-0.71
2007	0	5.82	-2.89	1.12	0.83	0.59
2008	0	3.82	2.11	0.89	0.57	0.48
2009	0	-2.93	1.47	-1.11	-0.52	-0.61
2010	0	1.82	-1.40	0.25	0.25	0.12
2011	0	-32.94	0.59	-4.39	-4.23	-2.28
2012	0	-15.11	-10.61	-1.53	-1.84	-0.78
2013	0	-12.88	-4.56	-2.14	-1.76	-1.11
2014	0	-4.67	-4.42	-0.79	-0.63	-0.42
2015	0	6.94	-1.58	1.06	0.93	0.55
2016	0	14.73	2.34	1.91	1.91	0.97
2017	0	11.99	4.74	1.45	1.55	0.72
2018	0	-22.55	3.80	-2.83	-2.89	-1.45
2019	0	-9.27	-7.14	-1.08	-1.20	-0.53
2020	0	-3.59	-2.93	-0.63	-0.51	-0.32
2021	0	-1.14	-1.27	0.01	-0.12	0.02
Average	0	-2.58	-0.85	-0.36	-0.33	-0.19
Drought Year Average	0	-9.67	-2.09	-1.36	-1.27	-0.71

Notes: Rows shaded in grey are drought years.

Table 6: Impact on Oklahoma Employee Compensation by Income Group under Potential Loss from Crop and Livestock Production and Indemnity (PL+Indemnity)($ millions)

Year	Income Group					
	<$20K	$20K-$40K	$40K-$60K	$60K-$80K	$80K-$100K	>$100K
2000	0	-1.68	-0.39	-0.32	-0.31	-0.52
2001	0	-0.65	-0.16	-0.17	-0.13	-0.3
2002	0	1.32	0.26	0.13	0.22	0.17
2003	0	3.08	0.61	0.37	0.52	0.58
2004	0	4.61	1.02	0.78	0.83	1.24
2005	0	3.64	0.77	0.53	0.64	0.83
2006	0	-7.55	-1.7	-1.36	-1.38	-2.21
2007	0	5.25	1.25	1.11	0.99	1.82
2008	0	3.46	0.88	0.88	0.67	1.48
2009	0	-2.67	-0.85	-1.09	-0.61	-1.88
2010	0	1.64	0.34	0.24	0.3	0.38
2011	-0.01	-29.64	-6.2	-4.35	-5.08	-7.06
2012	0	-13.57	-2.64	-1.52	-2.23	-2.4
2013	0	-11.6	-2.6	-2.11	-2.11	-3.45
2014	0	-4.2	-0.93	-0.78	-0.75	-1.31
2015	0	6.25	1.37	1.05	1.11	1.7
2016	0.01	13.24	2.76	1.9	2.29	3.01
2017	0	10.78	2.21	1.44	1.87	2.22
2018	-0.01	-20.27	-4.16	-2.81	-3.47	-4.48
2019	0	-8.33	-1.7	-1.07	-1.44	-1.63
2020	0	-3.24	-0.75	-0.63	-0.61	-1
2021	0	-1.02	-0.15	0.01	-0.15	0.06
Average	0	-2.33	-0.49	-0.35	-0.4	-0.58
Drought Average	0	-8.7	-1.85	-1.35	-1.52	-2.18

Notes: Rows shaded in grey are drought years.

Table 7: Impact on Total Industry Output (TIO) by Regions in Drought Years ($ millions)

Year	PL			PL+Indemnity		
	R-HJT	R-KG	ROOK	R-HJT	R-KG	ROOK
2000	-24.94	-0.17	-0.47	-13.38	-0.11	-0.24
2001	-11.57	0	-0.34	-0.69	0.04	-0.18
2006	-103.38	-0.54	-1.98	-61.61	-0.34	-1.08
2009	-78.84	-0.39	-2.28	-7.22	-0.01	-0.43
2011	-331.27	-1.82	-5.29	-238.38	-1.4	-3.47
2012	-117.86	-0.63	-1.23	-11.6	-0.19	0.42
2013	-156.69	-0.66	-3.16	-68.98	-0.23	-1.13
2014	-53.27	-0.02	-1.26	9.81	0.31	0.36
2018	-208.76	-0.76	-3.29	-122.28	-0.39	-1.87
2019	-83.94	-0.42	-1.08	-48.73	-0.27	-0.57
2020	-46.08	-0.13	-0.98	-31.21	-0.07	-0.76
2021	-1.29	-0.04	0.25	5.28	-0.01	0.35
Average	-103.55	-0.47	-1.71	-52.89	-0.24	-0.74

Notes: PL: potential revenue loss from crop and livestock production; PL+Indemnity: potential revenue loss from crop and livestock production with indemnity payments. R-HJT: region encompassing Harmon, Jackson, and Tillman counties; R-KG: region encompassing Kiowa and Greer counties; ROOK: rest of the counties in Oklahoma.

Table 8: Impact on Employment by Regions in Drought Years (number of jobs)

Year	PL			PL+Indemnity		
	R-HJT	R-KG	ROOK	R-HJT	R-KG	ROOK
2000	-155	-1	-2	-83	-1	-1
2001	-72	0	-1	-2	0	0
2006	-649	-4	-9	-389	-2	-5
2009	-467	-2	-8	-29	0	-1
2011	-2,210	-13	-26	-1,625	-10	-18
2012	-826	-5	-8	-145	-2	0
2013	-987	-4	-13	-444	-2	-5
2014	-343	0	-5	43	2	1
2018	-1,380	-5	-16	-828	-3	-9
2019	-537	-3	-6	-310	-2	-3
2020	-275	-1	-4	-179	0	-3
2021	-13	0	0	29	0	1
Average	-659	-3	-8	-330	-2	-4

Notes: PL: potential revenue loss from crop and livestock production; PL+Indemnity: potential revenue loss from crop and livestock production with indemnity payments. R-HJT: region encompassing Harmon, Jackson, and Tillman counties; R-KG: region encompassing Kiowa and Greer counties; ROOK: rest of the counties in Oklahoma.

Table 9: Impact on Total Value-Added (TVA) by Regions in Drought Years ($ millions)

Year	PL			PL+Indemnity		
	R-HJT	R-KG	ROOK	R-HJT	R-KG	ROOK
2000	-8.91	-0.06	-0.22	-4.74	-0.04	-0.11
2001	-2.79	0.00	-0.15	2.00	0.02	-0.07
2006	-37.64	-0.21	-0.92	-23.95	-0.14	-0.51
2009	-16.75	-0.11	-0.97	1.95	0.01	-0.17
2011	-139.67	-0.77	-2.56	-106.01	-0.60	-1.72
2012	-60.58	-0.31	-0.68	-15.12	-0.11	0.13
2013	-55.83	-0.26	-1.45	-29.03	-0.11	-0.55
2014	-17.58	-0.01	-0.57	-0.98	0.10	0.13
2018	-90.64	-0.36	-1.62	-54.85	-0.19	-0.93
2019	-38.90	-0.19	-0.56	-23.13	-0.12	-0.30
2020	-15.52	-0.05	-0.45	-8.98	-0.02	-0.34
2021	-4.43	-0.03	0.09	-1.72	-0.02	0.14
Average	-40.77	-0.20	-0.84	-22.05	-0.10	-0.36

Notes: PL: potential revenue loss from crop and livestock production; PL+Indemnity: potential revenue loss from crop and livestock production with indemnity payments. R-HJT: region encompassing Harmon, Jackson, and Tillman counties; R-KG: region encompassing Kiowa and Greer counties; ROOK: rest of the counties in Oklahoma.

for policymakers, risk-management advisors, extension agents, and farm decision-makers.

The three-county region's economy is particularly susceptible to drought due to its reliance on crop and livestock production, agricultural sales and services, and agricultural processing. Although drought effects were significant, some mitigating factors included diversified production activities and enrollment in FCIP. The bumper wheat crop in 2012 and the record-high cattle prices following the cattle cull of 2012 meant agricultural operations that included those industries experienced less severe loss during the widespread drought in high-loss activities like cotton and hay production. Further, the USDA Census of Agriculture indicates an increased adoption of cover crops, no-till, or conservation tillage since 2000 (NASS, 2017). The cause of that increase in adoption has not been fully explored. However, increased drought incidence and improved technology and experiential knowledge may have contributed to this. Activities that mitigate the severity of drought damages can potentially reduce the volatility in commodity supply and reduce the cost of the FCIP, as added societal benefits.

FCIP net indemnity payments varied by year but reduced loss by an average of 50% over the study period, during which widespread drought occurred in the region (2000-2001, 2006, 2009, 2011-2014, and 2018-2021). Producers who purchased FCIP recovered some drought-related losses compared to those who did enroll. However, the effects of FCIP indemnities did not stop at the producers; they rippled through the economy as those who received indemnity payments continued making transactions with related sectors.

There are research limitations and caveats. We only considered the ceteris paribus effects of insurance safety nets and the agricultural sector. Therefore, we are not capturing the effects of drought insurance on other industries. This study only focused on the federal crop insurance program (FCIP). We are aware that there are a variety of other insurance and disaster programs that severe drought events may trigger. For example, the federal disaster program Livestock Forage Program addresses supplemental cattle feeding costs and cattle revenue lost from forced sales due to insufficient forage. Cattle producers also have access to the Pasture Rangeland and Forage program, a precipitation insurance policy for cattle producers. This study could be expanded to account for disaster programs available under drought fully.

Similarly, we did not account for Small Business Administration disaster programs for non-agricultural businesses or business interruption insurance for recreation companies. Further research could examine ad hoc and permanently authorized disaster programs besides FCIP. In addition, the role of conservation programs such as no-till, conservation till, and cover crops in mitigating drought effects and reducing the cost of the FCIP should be explored in more detail for this drought-prone region.

Our estimates do not directly capture spillover from neighboring Texas counties that might also experience drought or prevent leakage into them. However, we note that Tillman-Jackson-Harmon counties are unique in that farms there irrigate from Lake Lugert-Altus and pump groundwater from the Blaine and Tillman Terrace aquifers. Considering spillover from neighboring Texas counties, these effects remain as leakage from the study area, Oklahoma, and elsewhere. As such, the results may be overstated or understated. The results are understated if the Texas counties are economically integrated with the target region (e.g., through supply chains, labor, or irrigation sources). Excluding them as a distinct region could overlook additional economic disruptions caused by the drought. If farms in Harmon-Jackson-Tillman counties rely on inputs (e.g., labor, machinery) from Texas, and those counties also face drought, the model could underestimate the full extent of the economic losses. Our results are overstated if some economic activity leaking into Texas would mitigate the drought's effect (for example, if Texas counties supply goods and services that could help buffer the impact in Oklahoma). Excluding them could result in overestimating how isolated the Oklahoma counties are, leading to an inflated estimate of the overall economic damage. The agricultural landscape of the target study area has also changed from 2001 to 2021. In Harmon, Tillman, and Jackson Counties, larger farms (more than 1,000 acres) grew by 12% from 2002 to 2017. Smaller farms (less than 1000 acres) declined by 40% (NASS, 2019a,b,c). This trend could enhance productivity due to economies of scale and increase the resilience of these farms when faced with natural disasters, such as droughts. In addition, many farm operators and their spouses also work in other sectors of the economy and rely on off-farm incomes (Brown and Weber, 2013). This aspect adds nuance to the research because the drought impacts extend beyond agriculture and affect sectors such as the services, finance, insurance, and real estate sectors.

The research provides a more comprehensive view of the impact of drought by analyzing the effects of drought across all economic sectors, including those where farm operators or their family members may be employed. If the regional and community leaders could anticipate how drought events affect their communities, they could determine which industries are most vulnerable to acute drought events. They can then use that information to target policies for the most vulnerable industries efficiently. Implications of the findings apply to similar regions whose economic industries are prone to drought conditions.

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APPENDIX

Table A1: Aggregation of Economic Industries

Aggregated Economic Industry	Economic Industries in Aggregation
Oilseed	Oilseed farming
Grain	Grain farming
Cotton	Cotton farming
Other Crop	All other crop production including hay, tree nut, fruit and vegetable, greenhouse, nursery, and floriculture production
Livestock	All animal production
Forestry	Forestry, forest products, and timber tract production; Commercial logging
Mining	All commercial mining and other nonmetallic minerals; drilling oil and gas wells; supportive activities for oil and gas operation
Services	All services
Utilities	Electric power generation, transmission and distribution; natural gas distribution
Water and Sewage	Water, Sewage, and other systems
Construction	All construction, maintenance and repair
Secondary Ag	Fertilizer, pesticide and other agricultural chemical manufacturing; farm machinery and equipment, lawn and garden equipment manufacturing
Other Manufacturing	Non-food manufacturing (not including agricultural and forestry input- or output-related manufacturing)
Primary Forestry Product	All primary forestry product manufacturing including sawmills, pulp mills, paper mills, paperboard mills, and cut stock, resawing lumber and planning
Secondary Forestry Product	All secondary forestry product manufacturing including wood windows and door manufacturing, prefabricated wood building manufacturing, paperboard container manufacturing, wood kitchen and cabinet and countertop manufacturing, etc.
Food and Fiber Product	All agricultural processing including, dairy, animal, food manufacturing, milling, and textiles
Wholesale	Wholesale
Retail	Dealers and retail stores
Transportation	All transportation including rail, water, truck, air, transit, pipeline, and couriers and messengers
Government	Schools, local and federal electric utilities; transit, state and local government enterprises; local and federal employment and payroll of state and federal government, rest of the world adjustment
FIRE	Depository and non-depository credit intermediation; brokerage; financial vehicles; insurance carriers, agencies, brokerage, and related activities; Real estate and owner-occupied dwellings
Misc	All other sectors (used goods, scrap, religious, business, and social organizations)