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The Stocking Impact and Financial-Climate Risk of the Livestock Forage Disaster Program

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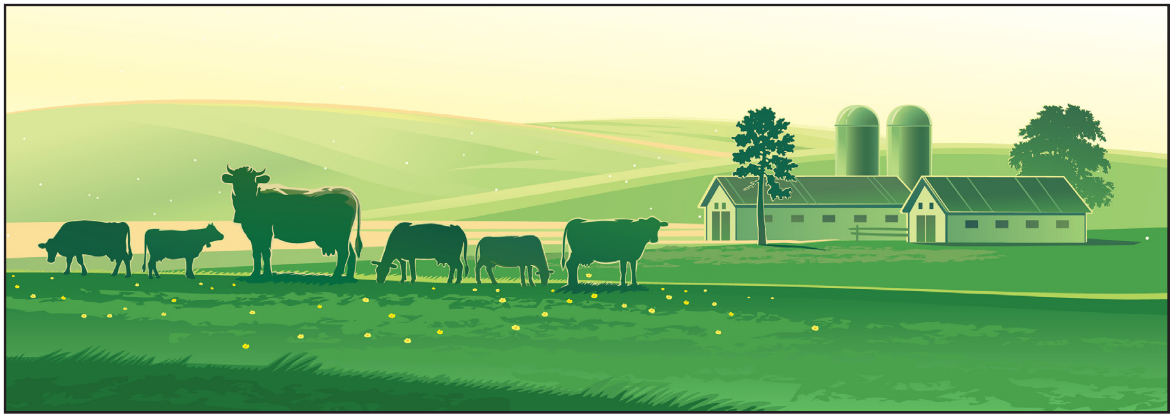

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Abstract

Drought imposes significant costs on the U.S. agricultural sector, particularly for livestock producers who rely on precipitation to grow forage. The U.S. Department of Agriculture (USDA) administers several programs to mitigate the economic costs of drought. One of these programs is the USDA, Farm Service Agency's (FSA) Livestock Forage Disaster Program (LFP), which provides payments to livestock producers impacted by drought. Program evaluation results suggest that producers in drought affected counties that received LFP payments achieved similar herd retention and liquidation outcomes as producers in less drought impacted counties that were ineligible for LFP payments. Simulation modeling results in this report suggest that LFP poses a financial-climate risk to the Federal budget. Depending on the future increase in greenhouse gas (GHG) emissions, annual Federal Government expenditures on LFP are projected to increase above the current average expenditures by 45–135 percent (in 2022 dollars) by 2100.

Keywords: drought, livestock, agricultural policy, financial-climate risk, Livestock Forage Disaster Program, LFP, greenhouse gas emissions, disaster assistance, climate projections

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A report summary from the Economic Research Service *January 2024*

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What Is the Issue?

Drought conditions, depending on the severity, extent, and duration, can cause a range of adverse impacts to the U.S. agricultural sector, from diminished crop yields and grazing conditions to widespread crop failures. The effects of drought are particularly pronounced for livestock producers as many of their operations rely on precipitation to grow forage crops to feed their herd. The U.S. Department of Agriculture (USDA) operates a range of programs designed to help mitigate the costs imposed by drought on livestock producers. Among these programs, the USDA, Farm Service Agency's (FSA) Livestock Forage Disaster Program (LFP) provides payments to producers whose forage production is diminished by drought. Despite the program disbursing more than $12 billion (in 2022 dollars) to producers between 2008 and 2022, no analysis has been conducted assessing how the program affects livestock producer herd retention and liquidation decisions. LFP also constitutes a potential financial-climate risk for the Federal Government (i.e., budgetary risks associated with administering programs and policies) as climate change is expected to increase the frequency and severity of drought conditions.

What Did the Study Find?

- The change in county beef cattle herd size in drought affected counties that received LFP payments was the same as it was in counties with less severe drought that did not receive an LFP payment.
- Modeling results suggest that program payments allow beef cattle producers in drought affected regions to make similar herd stocking and liquidation decisions as producers in regions experiencing less severe drought.
- In the moderating and middle-of-the-road greenhouse gas (GHG) emission scenarios, modeling results indicate that Federal Government expenditures on LFP will increase by 45 percent and 65 percent (in 2022 dollars), respectively, by the end of the 21st century compared with average expenditures between 2014 and 2022.

ERS is a primary source of economic research and analysis from the U.S. Department of Agriculture, providing timely information on economic and policy issues related to agriculture, food, the environment, and rural America.

- Under high and accelerating emission scenarios, results suggest that Federal Government expenditures on the program will increase by more than 100 percent (in 2022 dollars) by the end of the 21st century compared with average expenditures between 2014 and 2022.
- How drought is defined and possibly updated over time under a changing climate could significantly alter the modeled financial-climate risk of LFP.

How Was the Study Conducted?

The study leveraged a mix of survey, administrative, and climatic data to assess the financial-climate risk of the Livestock Forage Disaster Program (LFP) and determine if the program achieved similar livestock herd retention and liquidation outcomes in drought-affected program-eligible counties as in counties not eligible for the LFP. Specifically, administrative data obtained from the USDA, Farm Service Agency on county-level program payments and eligibility periods were combined with survey data collected by USDA, National Agricultural Statistics Service (NASS) on county-level beef cattle herd size and data characterizing county-level drought conditions reported by the U.S. Drought Monitor. These data were used to sort counties into groups that were eligible for LFP versus those counties that were nearly eligible for the program. Aggregate county herd size outcomes for beef cattle were then compared between these two groups using a matching panel data econometric model to estimate how subsequent herd sizes compare between the two groups.

To model the financial-climate risk of LFP, this report used outputs from an ensemble of climate models to project future drought conditions under a range of emission scenarios. These modeling outputs were combined with econometric estimates of the relationship between county-level LFP payments and herd sizes based on different program eligibility thresholds. Climate projections and econometric model estimates were used together to simulate future program payments across a range of emission scenarios and methodologies for defining drought.

The Stocking Impact and Financial-Climate Risk of the Livestock Forage Disaster Program

Introduction

Climate change is already impacting many sectors of the U.S. economy (U.S. Global Change Research Program (USGCRP), 2018). The agricultural sector is particularly vulnerable to climate change as crop yields, forage availability, and farm profits depend on evolving climatic conditions (Hsiang et al., 2017; Malikov et al., 2020). The Federal Government administers various programs within the agricultural sector to support climate change resilience and risk mitigation and to diminish farm income volatility (Baldwin et al., 2023). The largest of these programs is the USDA, Risk Management Agency's (USDA, RMA) Federal Crop Insurance Program (FCIP), which provides insurance to producers to compensate for losses due to natural causes such as drought, flooding, disease, and pests (Crane-Droesch et al., 2019; Glauber, 2013). The Federal Government also operates several programs specifically aimed at mitigating risk within the U.S. livestock sector (MacLachlan et al., 2018).[1] This report focuses on one of these programs, the USDA, Farm Service Agency's (USDA, FSA) Livestock Forage Disaster Program (LFP), which provides payments to livestock producers impacted by drought or wildfire. Specifically, this report presents an analysis that models how LFP payments affect subsequent beef cattle herd stocking decisions in addition to the Federal Government's financial-climate risk associated with the program under different greenhouse gas (GHG) emission scenarios.[2] [3]

Drought is a persistent threat to the U.S. agricultural sector (Kuwayama et al., 2019; Strzepek et al., 2010). Projections of climate in the United States have suggested that drought conditions may become more frequent and intense in the future, even in regions where total precipitation is projected to increase as precipitation events become less frequent but more intense (Lehner et al., 2017; Leng & Hall, 2019; Zhao & Dai, 2017). Livestock producers are particularly vulnerable to drought as farms rely on precipitation to grow forage

[1] USDA offers several insurance products tailored to meet the needs of the livestock sector. USDA, RMA supports the following programs: The **Dairy Revenue Protection Plan** provides protection against decreased yield or price revenues associated with milk sales from dairy cows. The **Livestock Risk Protection** program insures livestock producers against losses associated with livestock prices. The **Livestock Gross Margin** program is available to both beef and dairy cattle producers and protects producers against losses in gross margin. The program likely covers losses associated with drought as feed costs often vary according to local and regional drought conditions. The **Pasture, Rainfall, and Forage (PRF)** insurance product is a rainfall index insurance product covering annual forage, apiculture, pasture, rangeland, and forage. It provides payments when precipitation dips below a threshold defined by a long-term average. A **Whole-Farm Revenue Protection** policy is also available to provide a risk management safety net for all commodities (including livestock) produced on a given farm under one insurance policy.

Additionally, USDA, FSA operates several programs: The **Livestock Indemnity Program** provides payments to livestock producers for livestock deaths in excess of normal mortality caused by an eligible loss condition such as adverse weather conditions, disease, and attacks by predators reintroduced into the wild by the Federal Government or protected by Federal law. The **Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish Program (ELAP)** was amended in 2021 to help cover the costs of transporting feed and forage or livestock for livestock producers affected by drought conditions. The **Noninsured Crop Disaster Assistance Program (NAP),** which provides assistance to producers of noninsurable crops to protect against natural disasters that result in lower yields or crop losses, or prevents crop planting. Producers must apply for NAP, which provides the basic coverage equivalent to the catastrophic-level risk protection plan of insurance. Crops grown for livestock production are eligible for NAP coverage. USDA, FSA also allows for **emergency haying and grazing on environmentally sensitive land enrolled in the Conservation Reserve Program (CRP).** Emergency haying and grazing of CRP enrolled acres are authorized on a case-by-case basis to provide relief to livestock producers in areas affected by severe drought or a similar natural disaster.

[2] Beef cattle refer to cattle raised for meat production. The national beef cattle herd refers to all beef cattle in the United States, including beef cattle breeding stock (cows and bulls).

[3] Throughout this report the term "financial-climate risk" refers to the budgetary risks borne by the Federal Government through the administration of programs and policies. Climate change also poses financial risks for individuals and firms; these risks are not considered in this report.

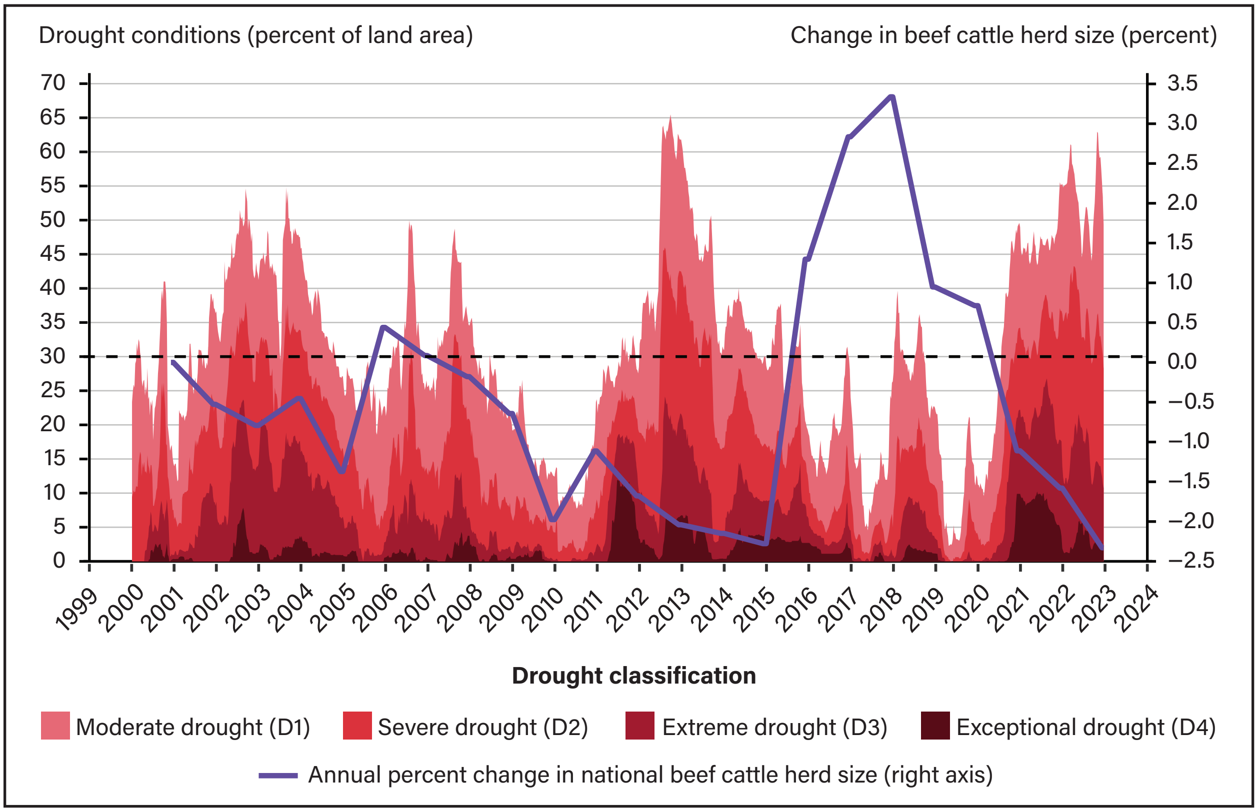
to feed their herds. When drought conditions diminish forage production and availability, livestock producers are generally forced to either buy supplemental feed and forage or liquidate some of their herd (Dhoubhadel et al., 2015; Patalee & Tonsor, 2021). Figure 1 charts the relationship between drought conditions in the United States and changes in the size of the national beef cattle herd. Generally, periods of more intense drought are associated with herd liquidation, while periods of less drought are associated with increases in herd size.[4]

This report assesses how LFP payments affect livestock producers'—specifically beef cattle producers—herd retention and liquidation decision making. To carry out this assessment, this report modeled how beef cattle herd size outcomes in counties that received LFP payments compare with counties that also experienced drought conditions but did not meet LFP eligibility criteria. Model results indicated that LFP payments allow beef cattle producers impacted by drought to behave similarly, in terms of aggregated herd retention and liquidation decisions, to beef cattle producers less affected by drought. This result suggests that the resources provided by the LFP potentially diminish the financial pressures driving herd liquidation decisions in response to drought conditions.

LFP aims to enhance the drought resilience of the livestock sector by providing payments to producers negatively impacted by drought. Climate change projections predict a hotter, drier future with increased drought incidence and severity (Lehner et al., 2017; Leng & Hall, 2019; Zhao & Dai, 2017). These projections underscore the potential importance of the program but also raise questions regarding future Government expenditures used to support LFP. Local, State, and Federal governments are becoming increasingly aware of the financial risks associated with projected emission scenarios (de Mello & Martinez-Vazquez, 2022; Gilmore et al., 2022; Gilmore & St. Clair, 2018). For LFP, projections of increasingly frequent and severe drought conditions have important implications for future Federal Government budget expenditures associated with operating the program (i.e., the financial-climate risk of LFP).

[4] Many other factors outside of local and regional drought conditions also affect livestock herd sizes and herd retention and liquidation decisions. These factors include prices, expectations of future prices, feed prices, expectations of future feed prices, extreme precipitation events, livestock marketing opportunities, and meat supply chain issues, as well as the natural cycles of contraction and expansion observed across differing livestock herds, which are related to the biological nature of livestock production and natural lifecycles of differing types of livestock (e.g., the cattle cycle).

Figure 1
Drought conditions in the continental United States and percent changes in the U.S. beef cattle herd size



Note: The left y-axis represents the percent of the continental United States experiencing differing levels of drought (in red bars) as defined by the U.S. Drought Monitor (USDM). The right y-axis presents the annual percent change in the national beef cattle herd (black line). USDM provides weekly hierarchical classifications of drought conditions in the United States. These classifications range from "None" to "D4: Exceptional Drought." Figure 1 plots the percentage of land area within the continental United States experiencing differing levels of drought ranging from "D1: Moderate Drought" to "D4: Exceptional Drought." The percentage of land area in the continental United States experiencing no drought ("None") and abnormally dry conditions ("D0: Abnormally Dry") are not plotted. The U.S. Drought Monitor's classifications are hierarchical in that more severe drought conditions encompass less severe conditions. For example, if a given region is classified as experiencing "D4: Exceptional Drought," then that region is also classified as experiencing "D3: Extreme Drought." Figure 1 does not include drought conditions in Hawaii, Alaska, or any U.S. territories. Although livestock production does occur in these regions and is important for local and regional markets, the scale of the production is relatively small compared with the continental United States, whereas the land area of these States (particularly Alaska) and territories is relatively large, which may potentially skew the relationship between drought conditions and the national beef cattle herd size. In 2017, the inventory of cattle and calves in Alaska and Hawaii jointly accounted for 0.06 percent of the national beef cattle inventory (USDA, National Agricultural Statistics Service (NASS), 2017). Percent change in the national beef cattle herd size is based on USDA, NASS statistics reporting the national beef cattle herd size as of January 1.

Source: USDA, Economic Research Service using USDM data and USDA, NASS data.

Financial-climate risks are particularly pertinent to administering LFP as eligibility and program payments are a function of drought severity as classified by the U.S. Drought Monitor (USDM).[5] If droughts increase in frequency and severity, then LFP expenditures may increase as well. This report addresses these financial-climate risk issues associated with LFP by integrating projections of future drought conditions with historical data relating drought severity and duration to LFP payments. This analysis suggests that, under high and accelerating emission scenarios, Federal Government expenditures related to LFP may increase by 113 percent

[5] The U.S. Drought Monitor's drought classifications are a single index reflecting drought conditions impacting many different sectors and the environment, not only the agricultural sector.

and 137 percent (in 2022 dollars), respectively, or $0.8 and $0.95 billion per year (in 2022 dollars) by the end of the 21st century compared with average aggregate annual expenditures between 2014 and 2022 (in 2022 dollars). For more information on emission scenarios considered in this report, see the "Emission Scenarios" box. In the moderating and middle-of-the-road emission scenarios, model results indicate that Federal Government expenditures related to LFP may increase by 45 percent and 65 percent (in 2022 dollars), respectively, or $0.3 and $0.45 billion per year (in 2022 dollars), by the end of the century compared with average aggregate annual expenditures between 2014 and 2022 (in 2022 dollars).

These projected increases in LFP payments are relatively small compared with current Federal Government expenditures associated with USDA, RMA's Federal Crop Insurance Program (FCIP). For example, the average annual Federal Government expenditures for FCIP exceeded $8 billion over the 2011–21 period (U.S. Government Accountability Office (U.S. GAO), 2023). However, given that FCIP premium rates before receiving subsidies are set to be actuarily fair, projected percent increases in FCIP expenditures under climate change are generally smaller than those predicted for LFP (Crane-Droesch et al., 2019).

This report also addresses the financial-climate risk of LFP under alternative drought classification methods as researchers have suggested that classifications of drought based on long-term historical climate conditions (e.g., USDM) may bias current and future drought assessments (Hoylman et al., 2022).[6] Results suggest that if drought classification methods adjust to reflect changing climate patterns (e.g., aridification), then the financial-climate risk of LFP diminishes.[7]

The modeling results assessing the financial-climate risk of the LFP in this report rely on several assumptions. The most restrictive of these assumptions is that the U.S. livestock sector will not adapt to evolving climatic conditions by changing production practices or relocating production to regions less impacted by drought. This is a strong assumption given the possibility that producers may adapt to changing patterns of drought, potentially decreasing the financial-climate risk of LFP. Additionally, the financial-climate risk model assumes that LFP characteristics (e.g., payment rates and eligibility criteria) and LFP-eligible grazing periods remain constant through time. These are also strong assumptions given the possibility of Congress changing LFP characteristics in response to increased program expenditures, LFP-eligible grazing periods altering due to climate change, and payment rates increasing if persistent and severe droughts impact commodity and feed markets. An increase in future LFP payment rates in response to drought conditions that impact commodity and feed markets can also potentially increase the financial-climate risk of LFP. Given the countervailing impacts of these two key modeling assumptions and the many other uncertainties when projecting LFP payments into the future, the results presented in this report likely fall in between the upper and lower bounds of future LFP payments, reflecting the high degree of uncertainty about the financial-climate risk posed by the program.

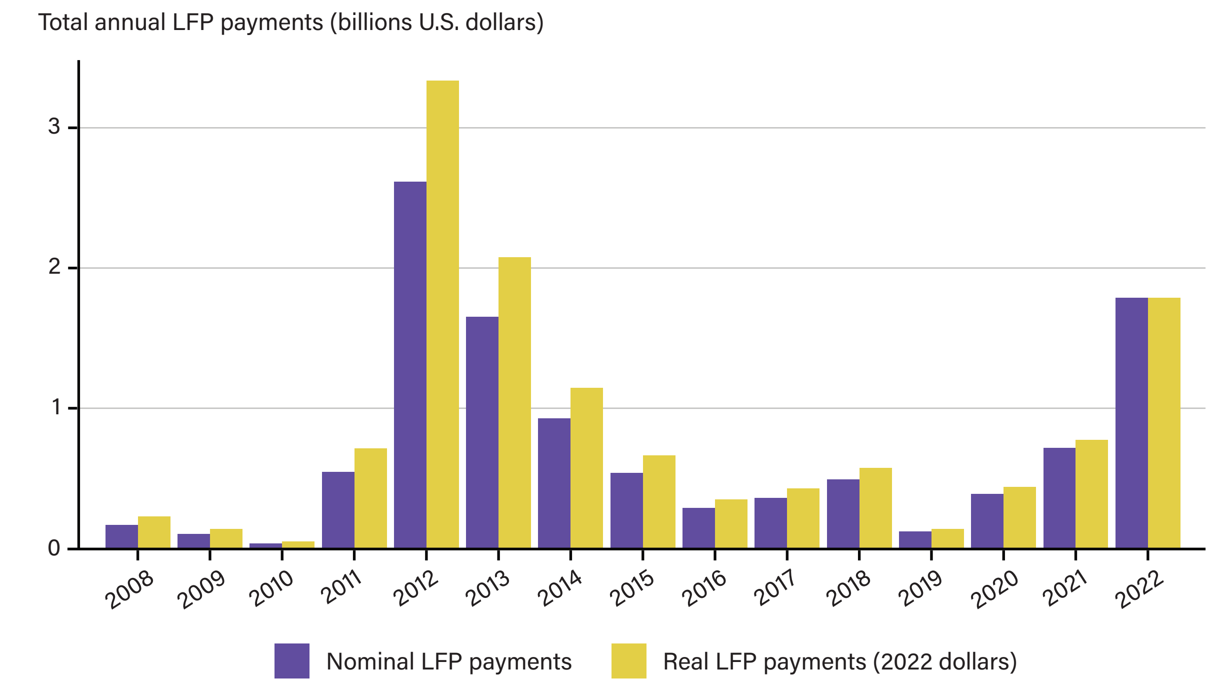
[6] The direction of the bias in drought classification and assessment introduced by relying on long-term historical climate data depends on the climatic trends observed in a given region. For example, if a given region is experiencing diminishing rates of precipitation over time (i.e., aridification), then drought assessments based on long-term data may bias drought classifications upward (i.e., classifying the region as experiencing drought when assessments based on more recent climatic data would not). In regions experiencing an increase in precipitation over time (i.e., humidification), drought assessments based on long-term data may bias drought classifications downward (i.e., classifying the region as not experiencing drought when assessment based on more recent climatic data would).

[7] Aridification refers to the process of a region becoming increasingly arid or dry (Overpeck & Udall, 2020). The process refers to a long-term change rather than seasonal variation and is generally measured as the reduction in average soil moisture content.

Livestock Forage Disaster Program Background

The Livestock Forage Disaster Program (LFP), initially established by the 2008 Farm Bill, provides compensation to livestock producers experiencing forage losses due to drought or wildfire (MacLachlan et al., 2018).[8] Figure 2 plots annual aggregate LFP payments between 2008 and 2022 in both real and nominal values. LFP payments peaked in 2012 at more than $2.5 billion (in nominal values) and more than $3 billion (in real values) as the majority of the major livestock production regions of the United States experienced unprecedented levels of drought (Rippey, 2015). LFP payments dispersed to livestock producers to compensate for forage losses arising from the 2012 drought were not sent to producers until 2014, after LFP was reauthorized from Congress and eligibility criteria was altered to no longer require prior insurance coverage.

Figure 2
Total annual nominal and real Livestock Forage Disaster Program (LFP) payments, 2008–22



Note: This figure differentiates between nominal and real aggregate annual LFP payments. Nominal aggregate annual LFP payments refer to the dollar amount of LFP payments distributed for losses each year. Real aggregate annual payments are these same payments but adjusted for inflation. Real annual aggregate LFP payments are presented in 2022 dollars. Aggregate LFP payments include both payments made to producers experiencing forage losses due to drought or wildfire on Federal rangeland leased to producers for grazing. The 2014 Farm Bill changed the eligibility requirements for LFP payments and authorized retroactive payments for producers impacted by drought conditions in 2012 and 2013 when much of the central United States experienced significant drought conditions (Rippey, 2015).

Source: USDA, Economic Research Service using USDA, Farm Service Agency data.

LFP was authorized in the 2008 Farm Bill which funded the program through 2011 and imposed a previous risk management purchase requirement for eligibility. Specifically, producers must have purchased private insurance, a policy through USDA's RMA, or coverage through USDA, FSA's Noninsured Crop Disaster

[8] Before the passage of the 2008 Farm Bill, some forage losses were covered by USDA, FSA's Feed Indemnity Program, which was an ad-hoc support program applied to certain areas impacted by hurricanes (USDA, FSA, 2005).

Assistance Program to be eligible for LFP payments (MacLachlan et al., 2018). LFP was suspended after 2011 until the passage of the 2014 Farm Bill, which allowed for retroactive payments to producers who had experienced drought-related losses in 2011, 2012, and 2013. Since 2014, the annual aggregate payments made to producers have averaged nearly $0.7 billion. Additionally, the LFP authorized in the 2014 Farm Bill ended the previous risk management purchase requirements for eligibility, ultimately opening program eligibility to nearly all U.S. livestock producers regardless of enrollment in private or Government insurance programs.[9] Currently, the maximum amount a given livestock producer can receive in LFP payments in a year is $125,000 (USDA, FSA, 2023a).[10]

LFP payments cover livestock feed costs on a per-animal basis for eligible expected losses due to drought. Only livestock that satisfy most of their net energy requirement of nutrition through grazing forage grasses or legumes are eligible for LFP payments (USDA, FSA, 2023). LFP payments are also dispersed to livestock producers whose operations are affected by wildfire. However, these wildfire payments are only available to cover forage losses occurring on federally managed rangeland and are generally minimal compared with payments made for forage losses arising from drought. USDA, FSA administers LFP and annually sets species-specific per-animal payment rates as well as county-level eligible grazing periods (for more information on LFP species-specific payment rates, see appendix A). LFP payments rates are set annually to reflect feed costs and generally aim to cover 60 percent of monthly per-animal feed costs.[11] LFP eligibility time periods can extend throughout the entire calendar year for some pasture types (e.g., full-season improved) in southern counties. Whereas in many northern counties, LFP eligibility time periods are shorter, in some cases lasting approximately 2 months.

To be eligible for LFP payments, the county in which a livestock producer operates must experience drought conditions that exceed a given threshold during the county's eligible grazing period associated with their pasture type.[12] [13] County-level drought conditions are classified weekly by USDM, which designates five levels of increasing drought severity ranging from “D0: abnormally dry” to “D4: exceptional drought.”

Livestock producers become eligible for 1 month of LFP payments when USDM classifies at least some area of the county where they operate as experiencing 8 or more consecutive weeks of severe drought (D2: severe

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[9] USDA, FSA does impose additional LFP eligibility based on income. Specifically, the livestock producers must have an average adjusted gross income (AGI)—both farm and nonfarm income, based on the 3 previous taxable years, of less than $900,000 (USDA, FSA, 2023a). Before 2012, LFP AGI eligibility criteria were based only on nonfarm income and the cap for eligibility was $500,000.

[10] Before 2019, LFP payment constraints (still $125,000) were based on the combination of both LFP payments and other USDA program payments. For example, in 2018 the $125,000 cap applied to the combination of LFP and Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) payments. Between 2012 and 2017, the $125,000 cap applied to LFP, Livestock Indemnity Program (LIP), and ELAP. Between 2008 and 2011, the $125,000 cap applied to LFP, Livestock Indemnity Program (LIP), and ELAP.

[11] In some scenarios, LFP payment rates differ from 60 percent of monthly per-animal feed costs. For example, if a livestock producer sold livestock or otherwise disposed of livestock due to drought in 1 or 2 of the previous production years immediately preceding the current production year, then that producer is eligible for a payment rate covering 80 percent of per-animal monthly feed costs. Livestock producers precluded from grazing their herd on federally managed land due to wildfire are eligible for a payment rate covering 50 percent of per-animal monthly feed costs. The length of these payments depends on the amount of time the producer was not able to graze their livestock on federally managed land, but not exceeding 180 days.

[12] USDA, FSA annually releases county-level data on LFP-eligible grazing periods for 13 differing pasture types, which have differing eligibility periods in some cases. Three of the pasture types (native pasture, full-season improved pasture, and warm season improved pasture) account for more than 94 percent of all LFP payments distributed between 2019 and 2022. The length of LFP-eligible grazing periods differ both between counties and between pasture types. For example, the short-season small grains eligibility period is generally much shorter than the full-season improved pasture type within the same county. Additionally, northern counties generally have much shorter LFP eligibility periods than southern counties, where eligibility periods for many pasture types often extend throughout the entire calendar year. LFP eligibility periods may change to encompass larger portions of the calendar year in many regions of the United States as evolving climate conditions extend the period during which forages grow and can be affected by drought conditions.

[13] Grazing losses occurring on irrigated pastureland are not eligible for LFP payments (USDA, FSA, 2023d). Pastureland that was previously irrigated, but not irrigated the year in which the grazing losses occurred, are eligible for LFP payments provided the land was not irrigated because of a lack of water for reasons beyond the producer’s control.

drought) during the county's eligible grazing period. Increasing drought severity increases the number of months of LFP payments a livestock producer is eligible to receive. For example, a livestock producer operating in a county that experienced 4 weeks of exceptional drought (D4) during the eligible grazing period (consecutive or nonconsecutive) is then eligible for 5 months of LFP payments. For a full schedule of LFP eligibility criteria and months of LFP payments, see table 1.

Table 1
Eligibility criteria for Livestock Forage Disaster Program (LFP) monthly payments

Months of LFP payments	Eligibility criteria
1	8 or more weeks of continuous severe drought (D2) during the county-eligible grazing period
3	At least 1 week of extreme drought (D3) during the county-eligible grazing period
4	4 or more weeks (not necessarily continuous) of extreme drought (D3) during the county-eligible grazing period OR At least 1 week of exceptional drought (D4) during the county-eligible grazing period
5	4 or more weeks (not necessarily continuous) of exceptional drought (D4) during the county-eligible grazing period

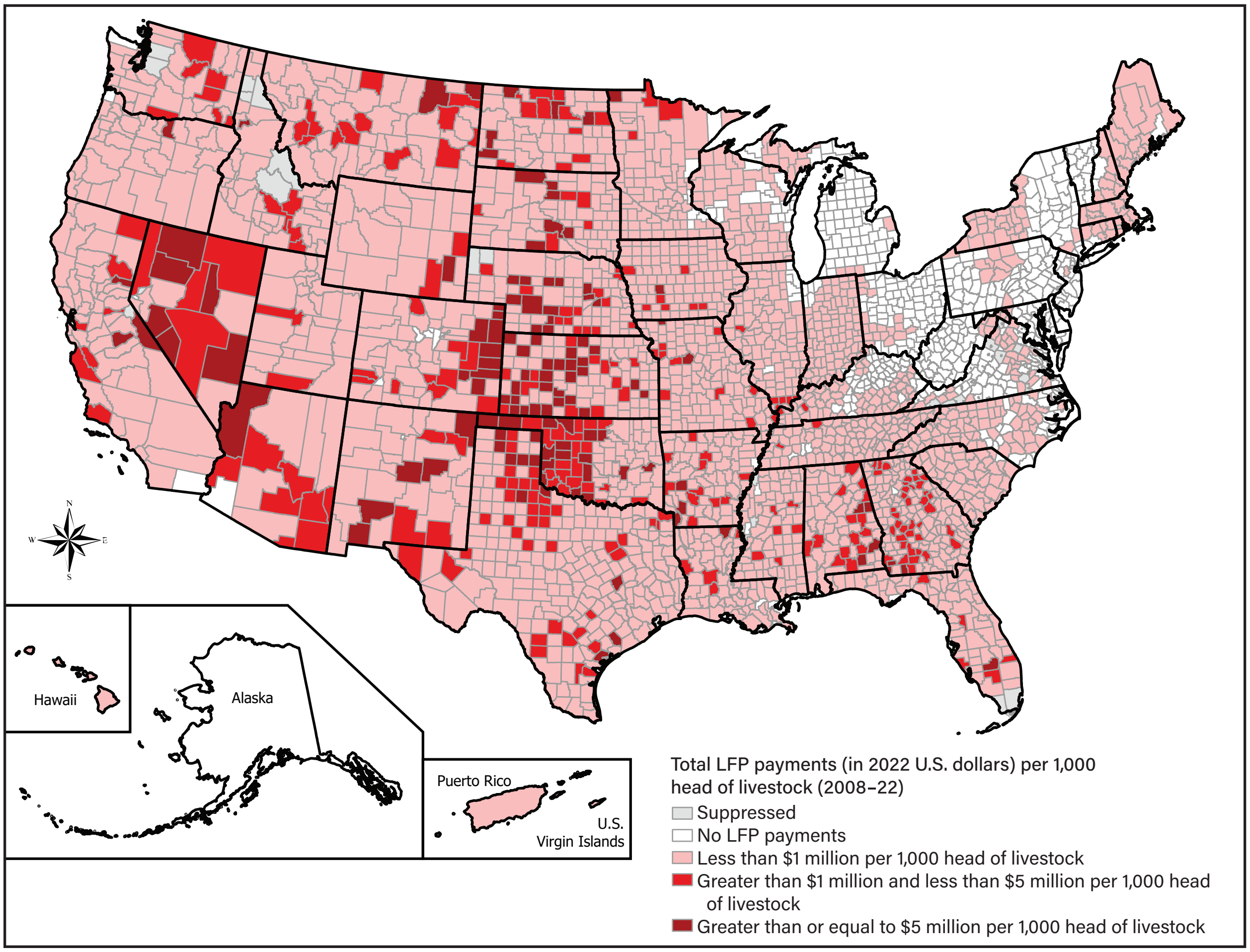
Note: This table presents the eligibility criteria for the USDA, Farm Service Agency's LFP as defined by county-level drought conditions classified by the U.S. Drought Monitor (USDM). Livestock producers become eligible if they are located within a county whose drought conditions, as defined by USDM, meets at least 1 of the eligibility criteria. USDM releases geospatially explicit data on a weekly basis, classifying drought conditions for all U.S. States and territories. These data are aggregated at the county level, and livestock producers with a given county become eligible if any regions of their county of operation meet the LFP eligibility criteria. Eligibility criteria are not hierarchical. For example, a county does not necessarily need to meet the criteria for 1 month of LFP payments to become eligible for 3 months of LFP payments. In some occasions, livestock producers may be eligible for 2 months of LFP payments if they are located within a county that experienced extreme drought during their county's eligible grazing period but their county's eligible grazing period for their forage type is less than 3 months.

Source: USDA, Economic Research Service using the USDA, Farm Service Agency, Livestock Forage Disaster Program Fact Sheet.

To receive LFP payments, an eligible livestock producer must submit an application to their local USDA, FSA office within 30 calendar days after the end of the calendar year in which the grazing loss occurred. Producers are also required to submit documentation demonstrating evidence of loss, proof that the affected grazing or pastureland is owned or leased, and risk in the production of forage on the grazing or pastureland. Contract producers are required to submit further documentation of their grower contract.

Figure 3 maps the distribution of total county-level LFP payments per 1,000 head of livestock between 2008 and 2022. Counties with the largest aggregate LFP payments are concentrated primarily in the western, southern, and central United States where drought conditions are generally more severe and common (Andreadis et al., 2005). Approximately 20 percent of counties in the continental United States received no LFP payments between 2008 and 2022. These counties are primarily located in the relatively more humid eastern United States and in urban counties (e.g., the Northeast region).

Figure 3
Total Livestock Forage Disaster Program (LFP) payments per 1,000 head of livestock by county, 2008–22



Note: Total county-level LFP payments per 1,000 head of livestock are calculated by aggregating county-level LFP payments (in 2022 U.S. dollars) between 2008 and 2022 for beef cattle, sheep, goats, and equine species within a county. Data for some counties are suppressed due to USDA, National Agricultural Statistics Service (NASS) data disclosure rules, while other data are suppressed because USDA, Farm Services Agency (FSA) data do not align with county geographic boundaries. In several cases, three adjacent counties are served by two USDA, FSA offices, and LFP payment data reflect the service areas of these offices rather than the geographical extent of the counties. Data for Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands are plotted at the State or territory level as some USDA, NASS regional data on livestock counts for these States and territories do not align with county or county equivalents. Livestock producers in Alaska received no LFP payments between 2008 and 2022. Aggregate LFP payments include payments made to producers experiencing forage losses due to drought and wildfire on Federal rangeland leased for grazing.

Source: USDA, Economic Research Service using USDA, FSA data; USDA, NASS data; and U.S. Department of Commerce, Bureau of the Census counties data.

Assessing the Stocking Impact of the Livestock Forage Disaster Program: Data and Methods

This report aimed to understand how eligibility for Livestock Forage Disaster Protection Program (LFP) payments impacts subsequent livestock herd retention and liquidation decisions. Specifically, this analysis, which focused on beef cattle producers, compared stocking outcomes in LFP-eligible counties with counties that nearly became eligible for LFP payments.

Data: The Impact of LFP Payments on Beef Cattle Herd Stocking Decisions

To model the relationship between LFP payments and beef cattle stocking decisions, this report focused on the 2014–22 period. LFP has been active since 2008; however, program eligibility was significantly changed in the 2014 Farm Bill (Public Law (Pub. L.) 113-79) to no longer require insurance purchase for eligibility. Additionally, the 2014 iteration of LFP authorized retroactive payments to producers who experienced forage loss due to drought in 2011, 2012, and 2013. The analysis of LFP payments' impact on beef cattle herd size does not include data for these years as these retroactive payments likely did not alter producers' decision making until the payments were dispersed in 2014.

To model how beef cattle stocking responds to LFP payments, this report leveraged data reported by USDA, National Agricultural Statistics Service (USDA, NASS). Specifically, data on county-level beef cattle herd size as of the beginning of January (which are reported based on data collected in USDA, NASS' Cattle Inventory survey) are used to characterize beef cattle herd retention and liquidation decisions with and without LFP payments (USDA, NASS, 2023).[14] [15] These data are county-level beef cattle herd size estimates through time generated with livestock producer survey responses. USDA, NASS' Census of Agriculture also collects data on county-level beef cattle herd sizes; however, these data are only collected every 5 years and are therefore unsuitable for the analysis of this report. Livestock producers raising other types of livestock other than beef cattle (e.g., sheep, goats) are also eligible for LFP payments.[16] However, except for dairy cattle, no data on county-level herd size are available annually between 2014 and 2022. This report opted to focus exclusively on beef cattle rather than both beef and dairy cattle as beef cattle production is generally more reliant on pasture-based forage than dairy cattle production.

Data reported by USDA, NASS based on information collected in the 2017 Census of Agriculture are used to characterize county-level differences in beef cattle production systems (USDA, NASS, 2017). Specifically, these variables include the percent of a county's harvested hay acreage that is irrigated, the percent of a county's agricultural land that is pasture, and the average county-level pasture rental rate. The analysis also incorporated several county-level climatic variables drawn from data reported by Oregon State University's PRISM Climate Group, including county-level, 30-year normal measures of total growing season precipitation and average growing season daily maximum temperature (PRISM, 2023).[17] County-level soil characteristics (e.g., percent of soil material sand and percent of soil material silt) drawn from data reported in Yun and Gramig (2019) were included in the analysis. Finally, this analysis controlled for other county-level USDA payments

[14] Data on county-level beef cattle herd size are not available for all counties either because: (1) There are no cattle within the county (e.g., urban counties); or (2) Data are suppressed due to USDA, NASS' data disclosure rules. USDA, NASS suppresses some county-level observations to avoid releasing personally identifiable information. Beef cattle inventory data are suppressed for several counties in the western United States with large inventories of beef cattle. These data are likely suppressed due to several producers and/or entities accounting for most of the counties' beef cattle inventory. These counties are not included in this report's analysis, which may bias results. However, characterizing this bias and testing for the robustness of results to their inclusion is not possible without the suppressed data.

[15] County-level data from USDA, NASS Cattle Inventory survey only differentiates cattle based on their use (i.e., beef or dairy) (USDA, NASS, 2023a). The data do not distinguish between grazed beef cattle and beef cattle on feed. Only beef cattle that receive the majority of their caloric needs from grazing are eligible for LFP payments. As such, the outcome variable used in this analysis includes counts of some cattle (those on feed) that are not eligible for LFP payments, which potentially introduces some variation in the analysis. Appendix G explores the implications of this inclusion by leveraging data from the 2017 Census of Agriculture on the count of cattle on feed by county and limiting the analysis to only those counties where cattle on feed account for less than 50 percent of the county's average total beef cattle inventory between 2014 and 2022 (USDA, NASS, 2017). Results within appendix G are similar to those presented in the main text.

[16] Data on LFP payments by livestock species are not available. However, it is likely due to the magnitude of the beef cattle industry compared with other livestock that most LFP payments are distributed to beef cattle producers. Specifically, according to the 2017 Census of Agriculture, beef cattle production generated more than 65 percent of the total market value of livestock sales eligible for LFP payments (USDA, NASS, 2017). The 65-percent estimate was generated by aggregating the market value of sales for all LFP-eligible livestock (i.e., beef cattle, dairy, sheep, goats, equine species, etc.) and calculating the percent of that aggregate attributable to beef cattle production. Hogs are not eligible for LFP payments.

[17] The growing season is May 1 through September 30.

made to livestock producers—specifically, USDA, RMA's Pasture, Rangeland, and Forage (PRF) indemnity payments, USDA, FSA's Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish Program (ELAP) payments for livestock transportation, and USDA, FSA's Noninsured Crop Disaster Assistance Program (NAP) payments for forage losses as well as Conservation Reserve Program (CRP) acreage authorized for emergency haying and grazing. For a summary of the statistics related to these control variables, see appendix B.

The modeling approach used to estimate the impact of LFP payments on subsequent beef cattle herd retention and liquidation decisions relied on comparing outcomes in LFP-eligible counties with outcomes in counties that also experienced drought during the study period but did not meet eligibility criteria during the year in question. LFP payments increase with more severe and longer droughts. The minimum criteria for 1 month of LFP payments is 8 consecutive weeks of severe drought (D2). More severe or longer lasting droughts increase the number of LFP payments that a producer is eligible to receive (table 1). To ensure that modeling results were based on comparisons of counties that experienced similar levels of drought, this report did not model the impact of LFP payments for counties eligible to receive more than 1 month of LFP payments, which corresponds to experiencing extreme (D3) or exceptional (D4) drought. Counties experiencing these more severe drought conditions are dropped from the sample of data used to estimate the model.

Modeling: The Impact of LFP Payments on Livestock Herd Stocking Decisions

To understand how LFP payments impact beef cattle producer herd retention and liquidation decisions, this report used a matching econometric model whereby outcomes in treatment counties (i.e., LFP-eligible counties) were compared with outcomes in matched control counties (i.e., LFP ineligible counties that experienced some level of drought but were otherwise similar to a given treatment county) (Imai et al., 2021). The primary outcome variable of interest was the log of county-level beef cattle herd size. The approach categorized counties into treatment and control groups for each year during the study period (2014–22). In a given year, treatment counties were those that experienced at least 8 weeks of consecutive severe drought (D2) during at least one of their LFP eligible grazing periods; received a nonzero quantity of LFP payments; and did not experience any extreme (D3) or exceptional (D4) drought conditions during their eligible grazing period. Control counties were those that experienced at least 1 week of D2 drought during at least one of their LFP-eligible grazing periods during 2014–22 and received zero LFP payments during the year in question.

Within this modeling framework, a given county can be classified as treatment in 1 year and control in the next (i.e., treatment reversal is possible). Standard panel data difference-in-difference estimators and staggered panel data difference-in-difference estimators, commonly used in the literature to estimate treatment effects, were not applicable as these estimators are not flexible to scenarios of treatment reversal (Athey & Imbens, 2022; De Chaisemartin & d'Haultfoeuille, 2020; Goodman-Bacon, 2021; Sun & Abraham, 2021). Instead, since the possibility of treatment reversal (i.e., a county being LFP eligible in 1 year and not in the next) is an important feature of LFP, this report used Imai et al.'s (2021) recently developed panel data matching estimator that is capable of estimating treatment effects (i.e., impact of LFP eligibility) in scenarios where the unit of observation (e.g., county) can move into and out of treatment through time.

The use of Imai et al.'s (2021) estimator is growing in applied research settings ranging from political science to conservation biology (Hope & Limberg, 2022; Kim & Li, 2023; Shiraef et al., 2022; West et al., 2022). The estimator relies on creating matched sets for each temporal period of the panel data that consisted of an individual treatment unit paired with a predefined number of control units. For this report, all units of observation within a given matched set had identical treatment histories leading up the time period in question. An example of a matched set in the context of the LFP was county X in 2016, which met LFP eligibility requirements and received LFP payments. This county was then matched to a predetermined number of control counties that were not eligible for LFP payments in 2016, but had the same treatment history as county X. Namely, if county X was eligible and received LFP payments in 2014 but not 2015, then all the control counties in the matched set were also eligible and received LFP payments in 2014 but not 2015. Basing the creation of matched sets on past treatment history ensured that matched sets were based on counties with similar previous drought conditions and LFP payments, which is akin to the parallel trends assumption required for estimating treatment effects in panel difference-in-difference models.

Matched sets were further refined by weighting control units based on their similarity to predefined treatment unit characteristics with more similar control units that received higher weights in the matched set. Specifically, within each matched set created for a given LFP-eligible county, control group counties that were most similar to the treatment county in terms of the refinement criteria received the highest weights. This refinement was important in that it ensured that control group counties were similar to the treatment county within a matched set. Given the importance of this refinement, this report used a suite of covariates as criteria for refining matched sets. Matched sets were refined based on drought conditions during a county's eligible grazing period, specifically weeks of moderate (D1) and severe drought (D2). This refinement ensured that causal estimates of LFP's impact were based on comparisons between LFP-eligible and nearly LFP-eligible counties. Matched sets were also refined based on geographical proximity of the treatment county to the control group counties in the matched set. Specifically, the latitude and longitude of the county's centroid were used for refinement, ensuring that counties nearest the treatment group county, which likely face similar input and output markets, received the highest weights.[18] Refinement was also based on county-level weather characteristics (average growing season precipitation and maximum temperature); county-level soil characteristics (percent of soil material sand and silt); county-level livestock production characteristics (percent of harvested hay acreage irrigated, the percent agricultural in pasture, and average pasture rental rate); county-level payments associated with other USDA programs focused on the livestock sector (USDA, RMA's PRF indemnity payments, USDA, FSA's ELAP payments for livestock transportation, and USDA, FSA NAP payments for forage losses); and county-level Conservation Reserve Program (CRP) acreage authorized for emergency haying and grazing.[19] Finally, the refined matched sets were used to estimate a nonparametric generalization of the standard difference-in-difference estimator. For additional technical details on the panel data matching estimator used in this report, see appendix C.

Assessing the Stocking Impact of the Livestock Forage Disaster Program: Results

Producer stocking decisions have important implications for livestock production profitability. The panel data matching estimator provided a means to assess how LFP payments affect subsequent beef cattle herd retention and liquidation decisions. Figure 4 presents results from this model that demonstrate how changes in the beef cattle herd size in LFP-eligible counties compare with changes in the beef cattle herd size in LFP-ineligible counties. Point estimates and confidence intervals generated by the matching econometric model, where the log of county-level beef cattle herd size is the outcome variable, were translated into percent changes using

[18] Regionally concentrated droughts likely impact regional forage markets (e.g., the price of hay), as drought decreases the quantity of forage produced as demand for supplemental forage increases among livestock producers. Ideally, refinement of matched sets would be based on these regional forage prices; however, county-level data on temporally disaggregated forage prices are not readily available (for more information on how these prices may be estimated for a small subset of States and regions, see Rowley (2022)). Refining matched sets based on geographical proximity (via county centroids) is a second best option to refining based on county-level forage prices. However, because county-level forage prices are not available nationally, refining based on geographical proximity is the only option to incorporate regional forage market outcomes in the analysis.

[19] Data on CRP emergency haying and grazing are only available for 2019 through 2022. Data on ELAP payments for livestock and forage transportation only exist for 2021 and 2022; prior to 2021, these payments were not available to livestock producers.

methods outlined in Halvorsen and Palmquist (1980). Figure 4 plots the estimated impacts of LFP payments (in percent) for alternative approaches to refining control counties within each matched set. The left-most estimate ((A) – on figure 4's x-axis) is generated without any matched set refinement. Subsequent specifications use an expanding set of additional variables to refine matched sets with the right-most estimate ((F) – on figure 4's x-axis) using drought conditions, county location, weather, soil, livestock production characteristics, and other USDA payments to livestock producers for refinement.[20]

Across all nearly all specifications, model results indicated that beef cattle stocking outcomes do not differ significantly between counties that received LFP payments and those counties that experienced less severe drought conditions. Point estimates of the impact of LFP ranged from 0.16 percent to 1.19 percent, but the confidence intervals of these point estimates suggested that these effect sizes were not significantly different than zero except for specification A, where matched sets were not further refined. These results suggest that LFP payments potentially ease some of the costs imposed on livestock producers by drought and allow these producers to behave similarly, in terms of average herd retention and liquidation decisions, to livestock producers less impacted by drought. For model results in table format that include the estimated parameter standard errors and P-values, see appendix D. Appendix E presents modeling results for a specification where percent change in a county's beef cattle herd size was the outcome variable of interest. Results of this specification were similar to those presented in figure 4. Finally, appendix I explores how differing matching algorithms impact modeling results and post-refinement covariate balance. These results indicate that while model results differ based on the type of matching algorithm used, the Mahalanobis matching algorithm used to generate figure 4 outperforms the other algorithms in terms of post-refinement covariate balance.

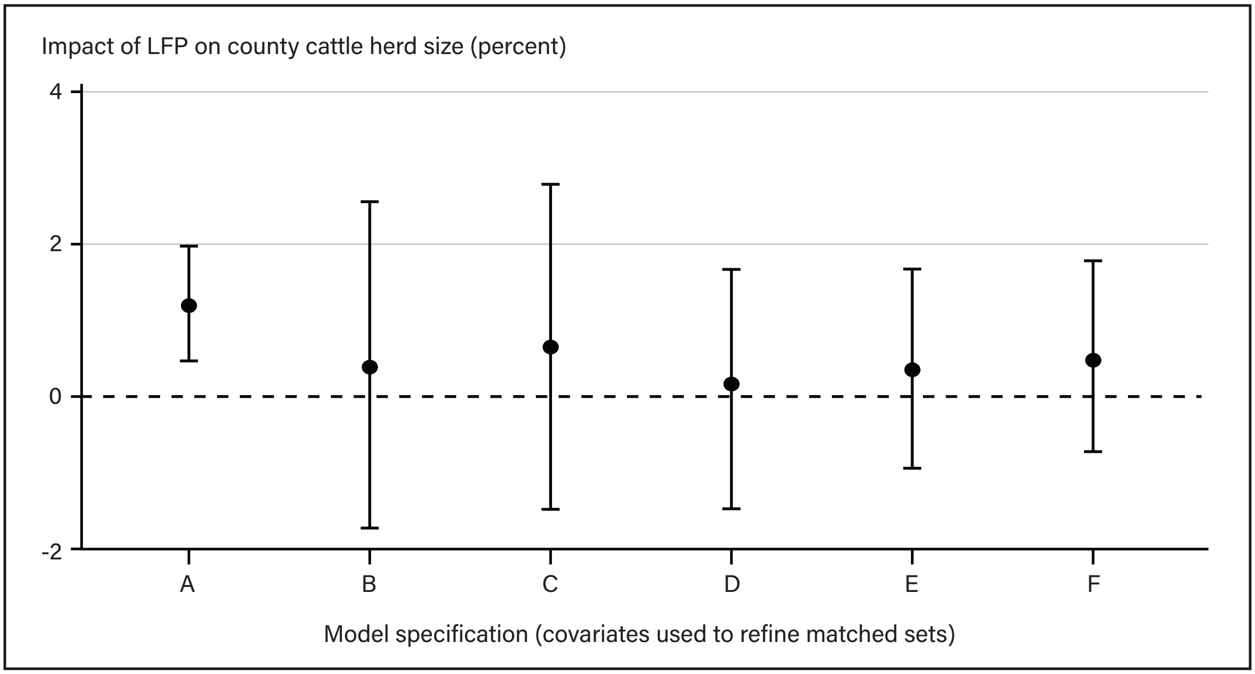
The results presented in figure 4 apply to aggregate beef cattle herd size outcomes, however, it may be the case that the impact of the LFP differs for certain types of beef cattle. For example, LFP payments may induce a producer to liquidate fewer beef cattle breeding stock or retain more replacement heifers. Although these mechanisms were potentially important for the impact of the program, data limitations have precluded analyzing how retention and liquidation decisions differ among specific types of beef cattle.[21]

[20] Specifications used the following covariates for matched set refinement: (A) no matched set refinement; (B) weeks of D1 and D2 drought and county latitude/longitude; (C) weeks of D1 and D2 drought, county latitude/longitude, and county average temperature/precipitation; (D) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, and county soil characteristics; (E) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, county percent of hay irrigated, county percent of ag land in pasture, and county average pasture rental rate; and (F) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, county percent of hay irrigated, county percent of ag land in pasture, county average pasture rental rate, county USDA, RMA PRF indemnities, county USDA, FSA NAP payments for forage losses, county acres of CRP emergency haying and grazing (2017–21), and county USDA, FSA ELAP payments for livestock and forage transport (2021–22).

[21] Specifically, analyzing differences in program impacts among differing types of beef cattle would require annual county-level data on the population of beef cattle stockers, breeding stock, recently purchased breeding stock, and calves kept for future breeding purposes. Unfortunately, these data are not available.

Figure 4

Causal impact of Livestock Forage Disaster Program (LFP) payments on subsequent county-level beef cattle herd retention liquidation decisions



Note: Figure 4 plots modeled point estimates (dots) representing the impact of LFP payments on subsequent county-level beef cattle herd size. The 95-percent confidence intervals are plotted as bars around each point estimate. Point estimates and confidence intervals are expressed in percentage terms using methods outlined in Halvorsen and Palmquist (1980). Mahalanobis distance matching is used to match treatment and control group counties. Differing point estimates (x-axis tick marks A–F) correspond to model specifications that use differing covariates to refine matched sets. These sets of covariates are as follows: (A) no matched set refinement; (B) weeks of D1 and D2 drought and county latitude/longitude; (C) weeks of D1 and D2 drought, county latitude/longitude, and county average temperature/precipitation; (D) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, and county soil characteristics; (E) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, percent of hay irrigated, percent of ag land in pasture, and average pasture rental rate; and (F) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, county percent of hay irrigated, county percent of ag land in pasture, county average pasture rental rate, county USDA, Risk Management Agency Pasture, Rangeland, and Forage (PRF) indemnities, county USDA, Farm Service Agency (FSA) Noninsured Crop Disaster Assistance Program (NAP) payments for forage losses, county acres of Conservation Reserve Program (CRP) emergency haying and grazing, and county USDA, FSA Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish Program (ELAP) payments for livestock and forage transport.

Source: USDA, Economic Research Service using USDA, Farm Service Agency data; and econometric modeling code provided by R package PanelMatch from Imai, K., Kim, I. S., & Wang, E. H. (2021). Matching methods for causal inference with time-series cross-sectional data. *American Journal of Political Science,* 67(3), 587–605.

The model estimates presented in figure 4 are based on comparing outcomes in nearly LFP-eligible counties to those that were eligible to receive 1 month of payment. However, counties experiencing more severe drought conditions (i.e., D3 or D4 drought conditions) were eligible to receive additional months of LFP payments. Appendix F presents modeling results for counties in the LFP treatment group experiencing more severe drought (i.e., up to 3 months of LFP payments). The magnitude of the stocking impact effect of the LFP was larger for this formulation of treatment but still relatively unprecise and not statistically different from zero. These results suggest that modeling assumptions regarding which counties comprise the treatment group do not significantly bias the estimated impact of LFP payments on beef cattle herd retention and liquidation decisions. Additionally, appendix H presents results splitting the sample of data used to estimate LFP impacts according to temporal changes in USDA, FSA's cap of maximum payment amounts to individuals/firms. These results suggest that changes in maximum payment amounts do not significantly change estimated program impacts.

Many factors outside of LFP payments influence livestock producer's herd retention and liquidation decisions (e.g., beef cattle cycle, market conditions, feed prices, and returns to alternative land uses outside of pasture-based livestock). The modeling results presented here aimed to minimize the impact of these factors by comparing outcomes in similar counties in the same year. However, it may be that unobserved county- or regional-level variables not accounted for in the model influenced the estimated impact of LFP.

The modeling and simulation results presented here pertain specifically to the impact of LFP on beef cattle producer's herd retention and liquidation decisions as the necessary data for the analysis are not available for other types of livestock outside of dairy cattle. However, this analysis' insights may be applicable to other livestock types also eligible for LFP payments, such as sheep and goat (for information on all livestock species eligible for LFP, see appendix A). These insights may be particularly applicable for livestock raised on pasture for human consumption. The ability to generalize these results stems from commonalities among many livestock production operations which are also prevalent in beef cattle production. Namely, many livestock producers operate by owning a herd of breeding stock and annually marketing the offspring of that herd.[22] It is possible that, like results suggested for beef cattle producers, LFP payments allowed other livestock producers affected by drought to operate similar to their counterparts who are less impacted by drought and achieve the same herd retention and liquidation outcomes. However, without annual data on herd sizes for nonbeef livestock, how LFP payments impacted herd retention and liquidation decisions on nonbeef cattle livestock operations remains unknown.

The Financial-Climate Risk of the Livestock Forage Disaster Program (LFP): Data and Methods

This section of the report outlines the data and methods used to assess the financial-climate risk of LFP and then presents the results of this analysis differentiating between differing emission scenarios and methods for assessing and categorizing drought. When characterizing data and methods used for this analysis, this report differentiated between data sources and methodologies used to (1) connect observed county-level drought severity to observed county-level LFP payments; and (2) project future drought conditions through 2100. Finally, this section concludes with a discussion of the model assumptions and limitations of the analysis.

Characterizing the Relationship Between Historical Drought Severity and LFP Payments

Assessing the financial-climate risk associated with LFP began with modeling the relationship between historical drought severity (as reported by the U.S. Drought Monitor (USDM)) and annual LFP payments. Specifically, this report uses annual, county-level data obtained by USDA, FSA on LFP payments made for LFP-eligible forage losses occurring during a given calendar year during the 2014–22 period.[23] These annual data were then joined with county-level data that described weekly drought severity reported by USDM, which were translated into months of LFP payments using the eligibility criteria (table 1) (Svoboda et al., 2002). Unlike the analysis of LFP's stocking impact, modeling the financial-climate risk of the program included the impact of counties eligible for LFP payments based on more severe drought conditions (i.e., D3

[22] While marketing herd offspring annually is the norm, marketing more frequently is possible for smaller ruminants (e.g., sheep and goats) with shorter gestation periods.

[23] Livestock producers have 30 days after the beginning of a new calendar year to report LFP-eligible forage losses. As such, some LFP payments made for grazing losses in a given year are not delivered to eligible livestock producers until the following year. When modeling the relationship between drought and LFP payments, this report used all LFP payments made to livestock producers within a given county for LFP-eligible forage losses during a given year, even when those payments were delivered in the subsequent year.

or D4). The inclusion of these counties in the analysis was important as producers located in these counties were eligible for more months of LFP payments and thus had a large influence on aggregate LFP expenditures. Finally, additional county-level information on livestock herd size (beef and dairy cattle, goats, sheep, donkeys, burros, horses, mules, and ponies), drawn from USDA, NASS' 2017 Census of Agriculture and Cattle Inventory surveys, were incorporated into the dataset (USDA, NASS, 2017; USDA, NASS, 2023).

These data were used together to estimate a panel data econometric model relating county-level drought conditions to LFP payments (i.e., the outcome variable) conditional on the size a given county's livestock herd. Including county-level herd size in the model was important as LFP payments are made on a per-head basis and county herd size explains a significant amount of the variation in county-level LFP payments.[24] The econometric model estimates a suite of parameters which describe how county-level months of LFP eligibility and livestock herd size impact total annual county-level LFP payments. The parameters estimated by the model are used to predict county-level LFP payments as a function of future drought conditions (for more details on the model and its results, see appendix J).

Projecting Future Drought Conditions Through 2100

Modeling to assess the financial-climate risk of the LFP used drought projections during the 2023–2100 period under four differing scenarios of greenhouse gas (GHG) emissions (i.e., moderating, middle-of-the-road, high, and accelerating emission scenarios) (for more information, see the "Emission Scenarios" box) and two alternative methods for classifying drought (stationarity and nonstationarity).[25] Future drought condition projections were paired with outputs from a model estimating the relationship between drought severity and LFP payments to predict future Federal Government expenditures associated with LFP.

Drought classifications have relied on historical climate data to characterize when temperature and precipitation patterns in a given region deviate from long-term averages. Many drought detection and classification data products have relied on more than 60 years of climate data to define long-term averages (e.g., USDM products). Recent research has highlighted how using these longer term climate records (more than 60 years) in drought detection and classification can bias drought severity assessments (Hoylman et al., 2022). Specifically, using these longer term climate records in drought assessment assumes stationarity in climate (i.e., climate records from more than 60 years ago would be similar to what is expected today). Anthropogenically driven climate change can make these common stationarity assumptions inappropriate to the extent that climate conditions from more than 60 years do not reflect current conditions. Rather than rely on stationarity assumptions, climate and weather sciences generally rely on 30-year climate normals, updated every decade, to describe average climate conditions in a manner consistent with climate change (i.e., nonstationarity drought classification) (Arguez & Vose, 2011).

Projected future drought conditions have been derived from an eight-member ensemble of climate projection models across differing emission scenarios (for more information, see "Emission Scenarios" box). The ensemble was selected to be consistent with the International Panel on Climate Change's (IPCC) assessment

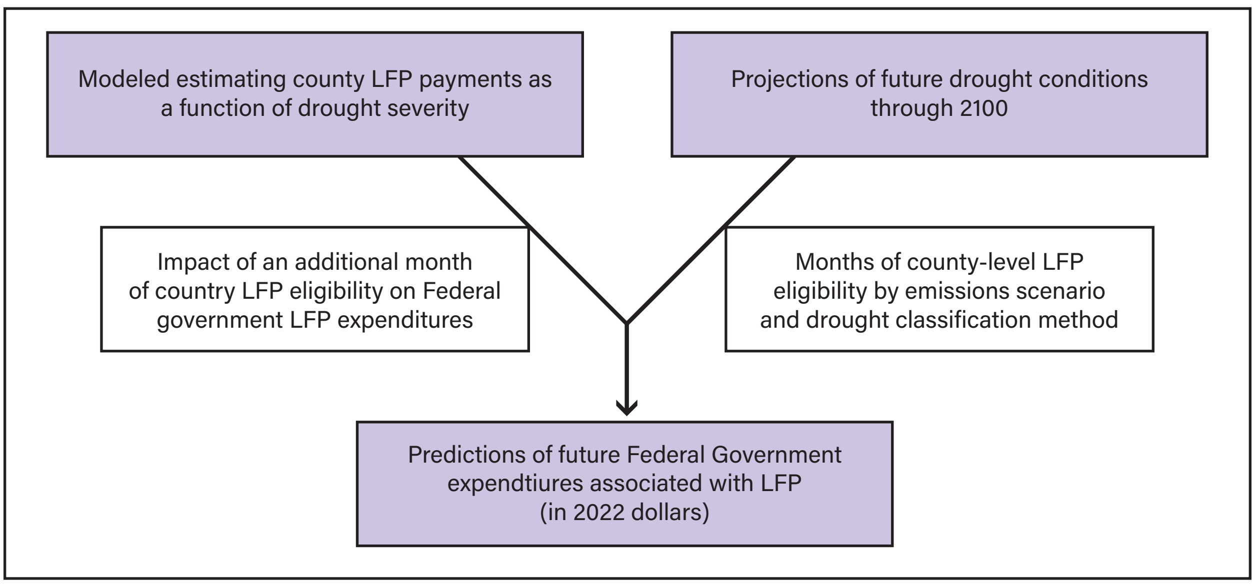
[24] Annual, county-level livestock herd size data were only available for beef and dairy cattle through data estimated by USDA, NASS' Cattle Inventory survey (USDA, NASS, 2023a). County-level stocks of other LFP-eligible livestock (e.g., sheep, goats) (for more information, see appendix A) were only available from USDA, NASS' Census of Agriculture, which collects data every 5 years (e.g., the 2012 Census of Agriculture and the 2017 Census of Agriculture). As 2017 is the only Census of Agriculture year within the time period considered in the analysis relating LFP payments to drought severity, this report leveraged data from that Census of Agriculture year to control for county-level herd size for other livestock types outside of beef and dairy cattle. This approach abstracted away from how interannual livestock herd size dynamics (i.e., for types of livestock outside beef and dairy cattle) may impact LFP payments.

[25] Stationarity projections of drought use over 60 years of climate data to define drought, while the nonstationarity definitions of drought use 30 years of climate data, updated every decade, to define long-term averages (Hoylman et al., 2022).

of the very likely range of Earth's equilibrium climate sensitivity, as assessed by Mahoney et al. (2022). The eight-member model ensemble includes ACCESS-ESM1.5 (Ziehn et al., 2020), CNRM-ESM2-1(Séférian et al., 2019), EC-Earth3 (Döscher et al., 2021) , GFDL-ESM4 (Dunne et al., 2020), GISS-E2-1-G (Kelley et al., 2020), MIROC6 (Tatebe et al., 2019), MPI-ESM1.2-HR (Müller et al., 2018), and MRI-ESM2.0 (Yukimoto et al., 2019). This report aggregated outputs from these models to a county-month unit of observation, and translated projections of future precipitation to the Standardized Precipitation Index (SPI) and the Standardized Precipitation-Evapotranspiration Index (SPEI). This report mapped these county-month SPI and SPEI projections to differing USDM drought classifications (D0: abnormally dry through D4: exceptional drought) using ranges reported by USDM.[26] Future USDM classification projections were coded as implied months of LFP payment eligibility for each unique combination of county, year, emission scenario, and drought classification method.

To predict future Federal Government expenditures associated with LFP, projected months of LFP eligibility under differing emission scenarios and methods of drought classifications were joined to econometric model output. Joining projections of future drought severity allowed this report to estimate the impact of an additional month of LFP eligibility on county-level LFP payments (in 2022 dollars). The only factor varying through time in these simulations was the number of months of LFP payments a given county was eligible to receive. The relationship between months of eligibility and county-level LFP payments was established based on the relationship between months of eligibility and payments observed between 2014 and 2022. This approach implicitly assumed that LFP payment rates will not evolve over time in response to drought.

Figure 5
Methodology used to predict future Livestock Forage Disaster Program (LFP) payments



Note: This figure conceptually plots the methods used to predict the Federal Government's future LFP expenditures. Future drought condition projections through 2100 are joined to outputs from a model estimating county LFP payments as a function of drought to forecast future LFP payments under differing emission scenarios and methods for classifying drought.

Source: USDA, Economic Research Service.

[26] USDM reported values of SPI and SPEI between -0.8 to -1.29 for D1: moderate drought; values between -1.3 and -1.59 for D2: severe drought; values between -1.6 and -1.99 for D3: extreme drought; and values less than -2.0 for D4: exceptional drought.

Modeling Assumptions and Limitations

Several key assumptions are implicit within this analysis of the Livestock Forage Disaster Program's (LFP) financial-climate risk. The first of these assumptions is that program characteristics (e.g., rules for determining payment rates and eligibility) do not change over time. These characteristics have remained constant since the most current iteration of LFP was formalized in the 2014 Farm Bill. However, these characteristics may change in the future—particularly if program expenditures substantially increase. Although these changes may be important for the program's financial-climate risk, modeling and predicting such changes is outside of the scope of this analysis.

The second assumption is that the geography of livestock production and production practices used by livestock producers will not adapt to changing climatic conditions. Climate change and the associated increasing intensity and duration of drought conditions may increase the risk and/or decrease the profitability of livestock production of some U.S. regions. In response, some livestock producers may exit the market or adapt their production practices (e.g., reduce herd sizes), or production may relocate altogether to other regions with more favorable production conditions (Patalee & Tonsor, 2021). These adaptations have the potential to decrease the program's future financial-climate risk, provided adaptations make livestock operations more resilient to drought conditions. Modeling future changes in the geography and production practices of livestock operations would involve integrating future climate projections and their impact on forage availability with producer market entry and exit as well as production decisions and is outside the scope of this report.

The analysis of LFP's financial-climate risk also assumes that the relationship between LFP payments and drought severity observed between 2014 and 2022 remains applicable to the 2023–2100 period. Future severe, multiyear, and geographically dispersed droughts, unlike those observed during 2014–22, potentially upend this assumption. Specifically, future droughts of this magnitude—particularly those affecting major feed-producing regions—may impact the average price of feed for a given livestock species. Accordingly, these feed and forage price changes would increase the LFP species-specific payments set by USDA, FSA, which are designed to cover 60 percent of monthly feed and forage costs. Potential increases in LFP payment rates in response to drought could potentially increase the program's future financial-climate risk. Incorporating these feed and forage prices into this report's analysis would involve modeling how potentially unprecedented levels of drought affect commodity markets as well as livestock feed and forage prices. Although this is an important research area, these analyses are outside the scope of this report.

Finally, the assumptions underpinning this report's analysis of LFP's financial-climate risk, as well as other uncertainties, can skew the projections of future LFP payments in countervailing directions. As such, the projections presented in this report have constituted neither an upper nor lower bound on potential future LFP payments. Instead, projections of future LFP payments presented here have reflected plausible financial-climate risk of the program and acknowledge a high degree of uncertainty.

Emission Scenarios

To project future U.S. drought conditions and associated Livestock Forage Disaster Program (LFP) expenditures, this report considered four different emission scenarios. These scenarios or Shared Socioeconomic Pathways (SSPs) were defined by the Intergovernmental Panel on Climate Change and were designed to span a range of modelled greenhouse gas (GHG) emission scenarios consistent with low to high warming levels (Riahi et al., 2016). Specifically, this report considered the following SSP scenarios: SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5. These scenarios use the naming convention of SSPx-y, where SSPx refers to the Shared Socioeconomic Pathway (SSP) describing the socioeconomic trends underlying the scenario and y refers to the approximate level of radiative forcing (in watts per square meter) resulting from the scenario in the year 2100.

Radiative forcing measures how much energy is coming into the atmosphere from the sun, compared with how much is leaving the atmosphere as infrared radiation. Before the industrial era, radiative forcing was balanced over extremely long periods of time and Earth's temperature remained relatively stable. The addition of GHG emissions to the atmosphere through anthropogenic factors, as well as other changes in land use and natural effects, have altered this balance at an unprecedented rate and now more heat enters the atmosphere than exits. Below are additional details describing each of the SSP scenarios modeled in the report.

Moderating Emissions (SSP1–2.6): Low GHG emissions, warming is limited to less than 2 °Celsius. Carbon dioxide (CO2) emissions decline to net zero by 2070.

Middle of the Road (SSP2–4.5): Intermediate GHG emissions, warming is limited to less than 3 °Celsius. Carbon dioxide emissions remain around current levels until 2050.

High Emissions (SSP3–7.0): High GHG emissions, warming is limited to less than 4 °Celsius. Carbon dioxide emissions approximately double from current levels by 2100.

Accelerating Emissions (SSP5–8.5): Very high GHG emissions, warming exceeds 4 °Celsius. Carbon dioxide emissions approximately double from current levels by 2050.

The Financial-Climate Risk of the Livestock Forage Disaster Program: Results

The Livestock Forage Disaster Program (LFP) poses a potential financial risk for the Federal Government as climate change projections have suggested that drought conditions may become longer lasting and more severe in the future.[27] Figure 6 presents results of future aggregate annual LFP payments through 2100 across a range of emission scenarios and methods for classifying drought. Specifically, the top panel of figure 6 shows projected LFP expenditures where future drought conditions are classified using the stationarity methodology, i.e., classifications based on longer term (more than 60 years) climate data and the current method

[27] LFP is somewhat unique in its financial-climate risk compared with other USDA risk management programs (e.g., Federal Crop Insurance Program (FCIP)) in that LFP is a disaster program where program benefits are available to all livestock producers who meet the drought severity and income eligibility criteria rather than an insurance program through which producers purchase disaster coverage. For example, the financial-climate risk of LFP compared with FCIP is quite different as FCIP premium rates would adjust to climate change-induced modifications of the risk of agricultural production in a given region, whereas LFP eligibility would remain constant unless Congress alters the program's characteristics.

used by the U.S. Drought Monitor (USDM). The bottom panel of figure 6 plots projected LFP expenditures for the case where future drought conditions are classified using the nonstationarity methodology, i.e., classifications based on 30-year, updated every decade, climate norms. Average annual LFP expenditures for each of the four emission scenarios considered are plotted as lines with shaded areas around the lines representing the 95-percent confidence interval around the annual average. LFP future expenditure projections do not incorporate variance in climate model outcomes, which would significantly broaden the 95-percent confidence intervals around the estimated mean— particularly for expenditure projections in the latter years of the 21st century where climate model uncertainty is larger. Future aggregate LFP payments are presented as values in 2022 dollars to avoid additional assumptions regarding average inflation rates through 2100. Additionally, projected LFP payments do not incorporate potential future LFP payments made covering forage losses arising from wildfire on federally managed grazing land. For results differentiating between stationarity and nonstationarity for each emission scenario see appendix L.

Results demonstrated that if drought classification methods continued relying on stationarity classification (i.e., longer term climate data), then average aggregate LFP payments are likely to increase substantially by the end of the 21st century—particularly in the higher emission scenarios. In the high (SSP3–7.0) and accelerating (SSP5–8.5) emission scenarios, average annual LFP payments during the 2070–2100 period are projected to increase by 113.0 percent (95-percent confidence interval (CI) (97.3–130.2 percent)) and 137.3 percent (95-percent CI (120.2–154.4 percent)), respectively, compared with the average annual payments between 2014 and 2022.[28] These percent changes in LFP payments under the high and accelerating emission scenarios translate into approximately a $0.8 billion (2022 dollars) and a $0.95 billion (2022 dollars), respectively, increase in average annual payments by the 2070–2100 period compared with average annual LFP payments between 2014 and 2022 (in 2022 dollars).

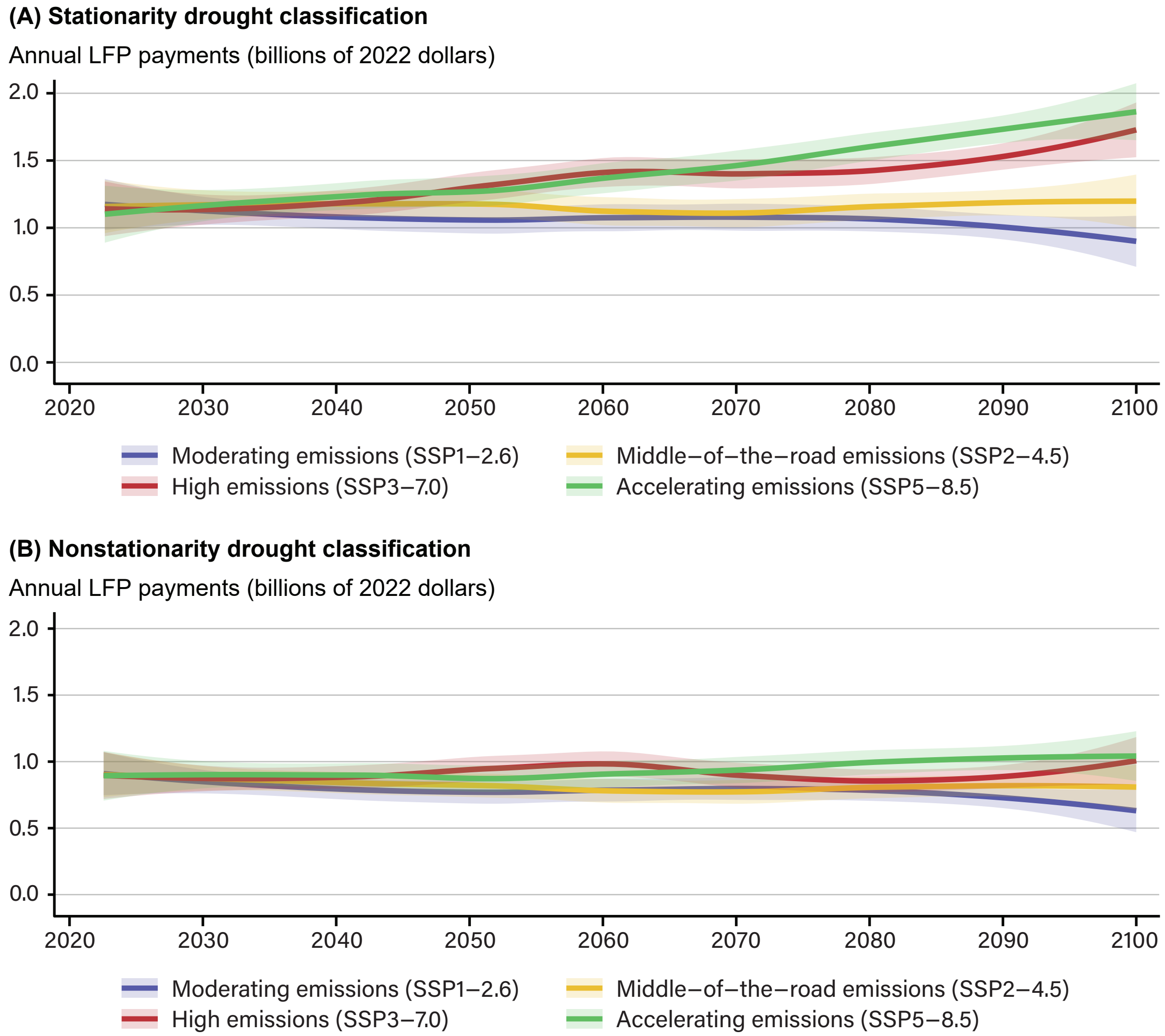
Payments did not increase as substantially in the lower emission scenarios relative to higher emission scenarios because the diminished rates of climate change decreased the severity and frequency of drought. Specifically, in the moderating (SSP1–2.6) and middle of the road (SSP2–4.5) emission scenarios, average annual LFP payments during the 2070–2100 period increased by 44.7 percent (95-percent CI (29.4–60.0 percent)) and 65.3 percent (95-percent CI (49.4–81.3 percent)), respectively, compared with average annual payments between 2014 and 2022. In dollar values, the moderating and middle-of-the-road scenarios are associated with an increase of approximately $0.3 billion (2022 dollars) and $0.45 billion (2022 dollars), respectively, in the annual average program payments for the 2070–2100 period compared with average annual LFP payments between 2014 and 2022 (in 2022 dollars).

Altering the methods used to detect and classify drought to use nonstationarity classification methods (i.e., 30-year climate norms, updated every decade) significantly reduced future LFP payment projections. In this scenario, relatively large increases in average aggregate annual LFP payments persisted for higher emission scenarios, whereas lower emission scenarios were associated with relatively modest increases in average LFP payments by 2100. When drought is classified via nonstationarity methods, model results suggested that for the high (SSP3–7.0) and accelerating (SSP5–8.5) emission scenarios, average annual LFP payments during the 2070–2100 period increased by 26.6 percent (95-percent CI (12.3–40.9 percent)) and 42.3 percent (95-percent CI (27.2–57.4 percent)), respectively, compared with average annual payments between 2014 and 2022. Meanwhile, in the scenarios of moderating (SSP1–2.6) and middle-of-the-road (SSP2–4.5) emissions, average annual LFP payments during 2070–2100 increased by 5.0 percent (95-percent CI (-8.1–18.0 percent)) and 13.8 percent (95-percent CI (0.2–27.5 percent)), respectively, compared with the average annual payments between 2014 and 2022.

[28] Confidence intervals (CI) are ranges around an estimate that convey the precision of the estimate. The 95-percent confidence interval refers to the range over which there is a 95-percent probability that the true value of the estimated statistic falls within.

Comparing projections of future LFP payments generated under stationarity and nonstationarity drought classification scenarios highlights the importance of drought classification methods in characterizing the financial-climate risk of LFP. Specifically, if the methods used to detect and classify drought do not adjust to future changes in climatic conditions (e.g., aridification), then LFP constitutes a potential financial-climate risk to the Federal Government's budget—particularly in higher emission scenarios, where average annual LFP payments are forecast to increase by more than 100 percent (2022 dollars) from their 2014–2022 average by the 2070–2100 period. If the methods used to detect and classify drought adapt to evolving climate patterns, then LFP constitutes a relatively minimal financial-climate risk compared with scenarios where drought detection and classification continues relying on climate stationarity assumptions. However, in the scenario where drought detection and classification are altered to adjust for changing climate conditions, the program characteristics of LFP may respond by adjusting in a manner that could change the relative financial-climate risk depending on how program eligibility and payments are altered.

Figure 6
Projected Livestock Forage Disaster Program (LFP) payments, 2023–2100



Note: This figure plots projected annual LFP payments and 95-percent confidence intervals around those projections between 2023 and 2100 for four differing emission scenarios (for more information, see "Emission Scenarios" box for more information). Panel (a) projects LFP payments using the current stationarity methods for drought classification (i.e., definitions for drought in a given region that are based on 60 or more years of historical climate data). Panel (b) uses a nonstationarity method to classify drought (i.e., definitions for drought in a given region that are based on 30 years of climatic data and updated through time to reflect a changing climate; for example, the aridification or humidification of a county or region). This report considered four different emission scenarios. These scenarios or Shared Socioeconomic Pathways (SSPs) were defined by the Intergovernmental Panel on Climate Change and were designed to span a range of modelled greenhouse gas (GHG) emission scenarios consistent with low to high warming levels (Riahi et al., 2016). Specifically, this report considered the following SSP scenarios: Moderating Emissions (SSP1–2.6): Low GHG emissions, warming is limited to less than 2 °Celsius. Carbon dioxide (CO2) emissions decline to net zero by 2070; Middle of the Road (SS–4.5): Intermediate GHG emissions, warming is limited to less than 3 °Celsius. Carbon dioxide emissions remain around current levels until 2050; High Emissions (SSP3–7.0): High GHG emissions, warming is limited to less than 4 °Celsius. Carbon dioxide emissions approximately double from current levels by 2100; Accelerating Emissions (SSP5–8.5): Very high GHG emissions, warming exceeds 4 °Celsius. Carbon dioxide emissions approximately double from current levels by 2050. Projected future LFP payments are generated using parameter estimates of a panel data econometric model estimating the relationship county-level aggregate annual LFP payments and the number of months of LFP payments producers within the county were eligible to receive. These parameter estimates are then joined to projected future drought conditions in the United States, which distill future climate conditions into U.S. Drought Monitor classifications and months of LFP eligibility using eight different climate change models. For each climate change model, annual aggregate LFP payments are generated by multiplying econometric model parameters by the number of LFP eligible months projected by the model and summing across counties. Annual results from each climate model are then aggregated and confidence intervals estimated using locally weighted (locally weighted scatterplot smoothing (LOESS)) regression techniques (Cleveland & Devlin, 1988). Future LFP payments are expressed in real terms (i.e., in 2022 dollars). Projected future LFP payments have an increasing trend in the stationarity drought classification scenario as the droughts become more frequent and severe in the future, compared with long-term historical climate conditions, increasing LFP eligibility, and LFP payments. Projected future LFP payments have a more static trend in the nonstationarity drought classification scenario as drought classification and assessment evolves through time to reflect changing climate patterns leading to less frequent drought designations and fewer producers becoming eligible to LFP payments.

Source: USDA, Economic Research Service using USDA, Farm Service Agency, parameter estimates data generated by econometric modeling, and of future drought condition projections across differing emission scenarios and models data.

Finally, the LFP payments' projected increases under differing emission scenarios are relatively small compared with current Federal Government expenditures on USDA's Federal Crop Insurance Program (FCIP). For example, the average Federal Government expenditures supporting the FCIP averaged $8 billion per year during the 2011–21 period (U.S. GAO, 2023). The annual LFP payment increases are projected to be more than $0.8 billion per year (in 2022 dollars) by the 2070–2100 period under the high and accelerating emissions and stationarity drought classification scenario, which would constitute approximately 10 percent of the current average annual Federal Government FCIP expenditures. However, given that FCIP premium rates before receiving subsidies are set to be actuarily fair, projected percent increases for FCIP expenditures under climate change were found to be generally smaller than those predicted for LFP (Crane-Droesch et al., 2019).

Conclusion

The USDA's Livestock Forage Disaster Program (LFP) provides payments to livestock producers whose forage production is impacted by drought or wildfire. This report answers two key questions relating to the program: (1) How has access to LFP payments affected livestock producers' herd retention and liquidation decisions to date?; and (2) What is the potential financial-climate risk of the program under differing greenhouse gas (GHG) emission scenarios?

Drought conditions have imposed significant costs on livestock producers as diminished precipitation decreases the availability of forage to meet livestock's nutritional needs. Feed and forage costs already account for a large share of the total livestock production costs. According to USDA, Economic Research Service's (ERS) Costs and Returns data, feed and forage costs account for approximately one-third of cow-calf producers' total costs (USDA, Economic Research Service (ERS), 2023). Drought conditions can further increase feed and forage costs and in some cases force producers to decide between buying additional supplemental feed and forage or liquidating some of their herd.

LFP has disbursed more than $12 billion (in 2022 dollars) in payments to livestock producers between 2008 and 2022. However, no research has investigated how these payments have affected livestock producer's herd retention and liquidation decisions. This report addressed this gap by modeling how LFP eligibility and payments have affected subsequent beef cattle herd retention and liquidation decisions. Model results comparing outcomes in LFP-eligible counties versus counties that nearly became eligible indicate that LFP payments enable beef cattle producers affected by drought to achieve similar outcomes—in terms of average whole-county herd retention and liquidation—to counties experiencing less severe drought conditions. These results suggest that LFP payments potentially ease some of the financial pressures imposed by drought on livestock producers, allowing beef cattle producers to liquidate less of their herds than expected in the absence of the program.

LFP eligibility is based on county-level drought conditions as classified by the U.S. Drought Monitor (USDM). Future drought condition projections under climate change have indicated that drought will become more frequent and severe in many regions of the United States (Lehner et al., 2017; Leng & Hall, 2019; Zhao & Dai, 2017). This projected increase in drought severity and frequency poses a potential financial-climate risk for the Federal Government's budget as it relates to LFP payments. Modeling results suggest that these drought risks may be significant, particularly in scenarios where emissions remain high and drought classification continues to be based on deviations from longer term climate (i.e., stationarity drought classification). In these higher emission scenarios, model results indicate that future annual average aggregate LFP payments could increase by more than 100 percent (in 2022 dollars) by 2100 compared with average payments between 2014 and 2022. Model results also highlight the importance of methods used for classifying drought under climate change. If the metrics used to classify drought are updated to reflect changing climate patterns (e.g., aridification), then the financial-climate risk of LFP significantly diminishes as fewer producers become eligible for program payments as the climate changes.

The analyses of the impact and financial-climate risk of the LFP presented in this report rely on several key assumptions that merit reiterating. Firstly, the analysis of the impact of LFP was based on comparing outcomes in counties that have qualified for 1 month of LFP payments based on experiencing 8 or more weeks of continuous severe drought (D2) to outcomes in counties that experienced less severe drought conditions. Livestock producers were able to receive additional months of payments if they experienced more severe drought conditions (i.e., extreme (D3) or exceptional (D4) drought). Outcomes in these counties were not included in the analysis of the program's impact on herd retention and herd liquidation. Secondly, the analysis of the LFP's financial-climate risk assumed that livestock producers do not adapt to evolving climatic conditions. However, livestock producers may adapt to changing climate conditions by altering their herd sizes, production practices, and/or where they choose to operate. These adaptations likely diminish LFP's financial-climate risk if the adoption of these practices leads to lower drought risk among livestock producers. Thirdly, the analysis of the financial-climate risk of LFP does not incorporate potential changes in LFP payment rates, which may increase if severe and consistent drought conditions impact commodity, feed, or forage markets. These potential LFP payment rate increases could increase the financial-climate risk of LFP, as higher LFP payments would increase Federal Government LFP expenditures.

Finally, important questions remain regarding the relationship between LFP and broad climate change adaptation within the livestock sector. For example, it remains unclear how short-term program payments interact with long-term climate change adaptation within the livestock sector. However, this analysis is outside the scope of this report, but it remains an important avenue for future research efforts.

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Appendix A: Livestock Forage Disaster Program Payment Rates

Table A.1

Livestock Forage Disaster Program payment rates by livestock type, 2019–23

Kind	Type	Weight range	2019	2020	2021	2022	2023
			2019 U.S. dollars	2020 U.S. dollars	2022 U.S. dollars	2022 U.S. dollars	2023 U.S. dollars
Beef cattle	Adult	Bulls, cows	29.34	31.89	31.18	47.29	58.12
	Nonadult	Greater than 500 pounds	22.01	23.92	23.38	35.47	43.59
		Less than 500 pounds	14.67	15.94	15.59	23.64	29.06
Dairy cattle	Adult	Bulls, cows	76.29	82.91	81.07	122.95	151.12
	Nonadult	Greater than 500 pounds	22.01	23.92	23.38	35.47	43.59
		Less than 500 pounds	14.67	15.94	15.59	23.64	29.06
Beefalo	Adult	Bulls, cows	29.34	31.89	31.18	47.29	58.12
	Nonadult	Greater than 500 pounds	22.01	23.92	23.38	35.47	43.59
		Less than 500 pounds	14.67	15.94	15.59	23.64	29.06
Buffalo/ Bison	Adult	Bulls, cows	29.34	31.89	31.18	47.29	58.12
	Nonadult	Greater than 500 pounds	22.01	23.92	23.38	35.47	43.59
		Less than 500 pounds	14.67	15.94	15.59	23.64	29.06
Sheep	All		7.34	7.97	7.79	11.82	14.53
Goats	All		7.34	7.97	7.79	11.82	14.53
Deer	All		7.34	7.97	7.79	11.82	14.53
Equine	All		21.71	23.60	23.07	34.99	43.01
Elk	All		15.85	17.22	16.84	25.54	31.39
Reindeer	All		6.46	7.02	6.87	10.42	12.80
Alpacas	All		24.17	26.27	25.68	38.95	47.88
Emus	All		15.02	16.32	15.96	24.20	29.75
Llamas	All		10.71	11.64	11.38	17.26	21.21
Ostrich	All					26.01	31.97

Note: This table presents livestock species-specific payments rates for the USDA's Livestock Forage Disaster Program (LFP) as defined by USDA, Farm Service Agency (FSA). These payments rates establish the amount paid per animal and per month. For example, if a livestock producer with 100 adult beef cattle (and no other livestock) were eligible for 1 month of LFP payments in 2023, then that producer would receive $5,812.00 in LFP payments (100 X $58.12 = $5,812.00). The "All" designation in the "Type" column indicates that the same LPF payment rate applies for a given species of livestock. For example, the "All" designation for sheep indicates that rams, ewes, and lambs all receive the same LFP payment rate. Producers raising ostriches became eligible for LFP payments in 2022; prior to 2022, ostrich producers were not eligible for LFP payments.

Source: USDA, Economic Research Service using data provided by USDA, Farm Service Agency in the Livestock Forage Disaster Program Fact Sheet (USDA, FSA, 2023a).

Appendix B: Summary Statistics for Outcome and Matched Set Refinement Variables in Livestock Forage Disaster Program Stocking Impact Analysis

Table B.1

Summary statistics for outcome and matched set refinement variables in Livestock Forage Disaster Program stocking impact analysis

Variable	N	Mean	St. dev.
Beef cattle herd size (head of beef cattle)	9,917	12,189.53	12,292.52
Growing season precipitation (millimeter)	9,917	507.30	167.94
Growing season average max temperature (Celsius)	9,917	25.91	3.42
Soil sand (percent)	9,917	34.24	20.07
Soil clay (percent)	9,917	27.66	9.12
Harvested hay, irrigated (percent)	9,917	11.14	23.69
Agricultural land in pasture (percent)	9,917	43.58	25.77
Pasture rental rate (dollars per acre)	9,917	23.08	13.59
USDA, RMA forage indemnities (dollars per year)	9,917	80,349.27	34,3547.80
USDA, FSA, NAP forage payments (dollars per year)	9,917	100.65	4,103.90
USDA, FSA, ELAP forage and livestock transportation payments (dollars per year)	1,062	939.91	12,514.57
CRP emergency haying and grazing (acres per year)	6,124	48.18	519.76

N = Count of observations. St. dev. = Standard deviation. RMA= Risk Management Agency. FSA = Farm Service Agency. NAP = Non-insured Crop Disaster Assistance Program. ELAP = Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish. CRP = Conservation Reserve Program.

Note: Table B.1 presents summary statistics for the variables used to assess the stocking impact of the Livestock Forage Disaster Program (LFP). Beef cattle herd size data are drawn from USDA, National Agricultural Statistics Service (NASS) Cattle Inventory surveys (USDA, NASS, 2023a). County-level, 30-year normals for growing-season precipitation and growing-season average maximum temperature are drawn from Oregon State University's PRISM climate group (PRISM, 2023). County-level soil characteristics are drawn from data reported by Yun & Gramig (2019). Percent of harvested hay irrigated and percent of agricultural land in pasture are drawn from the 2017 Census of Agriculture (USDA, NASS, 2017). The average pasture rental rate is drawn from the USDA, NASS Cash Rents survey (USDA, NASS, 2023b). USDA, RMA forage indemnities were drawn from USDA, RMA's Summary of Business reports (USDA, RMA, 2023d). USDA, FSA's ELAP payments for forage and livestock transportation were obtained from USDA, FSA. USDA, FSA acres of CRP land used for emergency haying and grazing were obtained from USDA, FSA. USDA, FSA's NAP payments for forage were obtained from USDA, FSA.

Source: USDA, Economic Research Service using USDA, National Agricultural Statistics Service (NASS) data (2017). *Census of agriculture*; USDA, NASS. (2023a). *Cattle inventory*; USDA, NASS. (2023b). *Cash rents*; PRISM Climate Group data (2023); Soil data from Yun, S. D., & Gramig, B. M. (2019). Agro-climatic data by county: A spatially and temporally consistent U.S. dataset for agricultural yields, weather and soils. *Data*, 4(2), 66; USDA, Risk Management Agency (RMA), Summary of Business Data. (2023b). *Livestock gross margin insurance cattle*, 2023; and USDA, Farm Service Agency data on county-level LFP payments by year.

Appendix C: Modeling the Stocking Impact of Livestock Forage Disaster Program Eligibility

The standard method for estimating causal effects from panel data is the two-way linear fixed effects regression (TWFE). In the context of the Livestock Forage Disaster Program (LFP), this model takes the following form:

C.1 $Y_{i,t} = a_i + \gamma_t + \beta X_{i,t} + \theta Z_{i,t} + \varepsilon_{i,t}$

Where $Y_{i,t}$ represents the log transformed annual beef cattle herd size in county *i* in time *t*. $Y_{i,t}$ is modeled as a function of a county-level fixed effect, a_i, a year fixed effect, γ_t, an indicator variable, $X_{i,t}$, denoting eligibility for LFP payments, with associated parameter β expressing the impact of LFP eligibility on $Y_{i,t}$, a matrix of time varying control variables, $Z_{i,t}$, with an associated vector of parameter estimates, θ, and an idiosyncratic error term, $\varepsilon_{i,t}$. Using this model to estimate the causal impact of LFP eligibility and payment faces three major empirical issues: (1) The timing of treatment (LFP eligibility and payment) differs across units of observation (i.e., counties); (2) Units of observation may receive treatment in multiple time periods; and (3) Treatment reversal is possible (i.e., a unit of observation may receive treatment in time period *t*, not receive treatment in time period *t+1,* and receive treatment in time period *t+2*).

Recent literature has emerged highlighting many of the pitfalls of the TWFE model when estimating causal effects (Athey & Imbens, 2022; De Chaisemartin & d'Haultfoeuille, 2020; Goodman-Bacon, 2021; Sun & Abraham, 2021). Particularly, the literature has noted that the standard TWFE model produces bias estimates when treatment is staggered over time across units of observation and proposes a suite of new estimators capable of dealing with staggered treatment implementation. However, these approaches do not allow for the estimation of causal effects under treatment reversal, which is possible in the context of the LFP. As such, this report leveraged a novel estimator, PanelMatch, which combines matching methods with a difference-in-difference estimator to model causal effects in the presence of treatment reversal (Imai et al., 2021).

PanelMatch introduces two key parameters to identify control units (i.e., the matched set) and to define the causal quantity of interest. These parameters, *F* and *L*, identify the temporal extent of the estimated causal impact and the number of periods of treatment history used to create matched sets, respectively. The PanelMatch model is capable of estimating both contemporaneous and noncontemporaneous treatment effects. This analysis of the LFP focused on contemporaneous effects of the program and *F* is set to 0. Although noncontemporaneous effects may be possible in the context of the LFP (i.e., impacts in a county's herd size in years after the county was eligible for LFP payments) these effects were likely small given the annual cyclical nature of most livestock operations. The parameter *L* defines the number of time periods of treatment history used to define matched sets, or the set of control group counties matched to a given treatment group county. This analysis sets *L* to equal 2, which corresponds to matching treatment and control counties based on 2 years treatment history before the year in question. The selection of *L* is part of the identification assumption and, thus, it is important to assess whether previous treatment status may act as a confounding variable that impacts both the current treatment and outcome (Imai et al., 2021). Given the values of *F* and *L*, the average treatment effect, ρ, on the treated takes the following form:

C.2 $\rho(F = 0, L = 2) = E[Y_{i,t}\left(X_{i,t} = 1, X_{i,t-1} = 0, \left(X_{i,t-1}\right)_{l=2}^{L}\right) -$

$Y_{i,t}\left(X_{i,t} = 0, X_{i,t-1} = 0, \left(X_{i,t-1}\right)_{l=2}^{L}\right) \mid X_{i,t} = 1, X_{i,t-1} = 0]$

Counties that receive LFP payments in year t are the treated units, $X_{i,t} = 1$. $Y_{i,t}\left(X_{i,t} = 1, X_{i,t-1} = 0, \left(X_{i,t-1}\right)_{l=2}^{L}\right)$ is the potential outcome for counties that received LFP payments and $Y_{i,t}\left(X_{i,t} = 0, X_{i,t-1} = 0, \left(X_{i,t-1}\right)_{l=2}^{L}\right)$ represents the counterfactual potential outcome. $\delta(F = 0, L = 2)$ represents the contemporaneous causal effect of LFP eligibility and payments on subsequent livestock herd retention and liquidation decisions. The causal interpretation of $\delta(F = 0, L = 2)$ depends on assumption that a potential outcome (e.g., livestock stocking decisions) in a given year depends on treatment history in the 2 previous years. Additionally, the model assumes no spillover effects between units of observation (i.e., a county's potential outcomes are only affected by its own treatment history).

The counterfactual outcome for treated counties cannot be observed, instead the potential outcome, δ, for counties not eligible for LFP is used:

C.3 $$\delta(F = 0, L = 2) = E\left[\left\{Y_{i,t}\left(X_{i,t} = 1, X_{i,t-1} = 0, \left(X_{i,t-1}\right)_{l=2}^{L}\right) \middle| X_{i,t} = 1, X_{i,t-1} = 0\right\} - \{Y_{i,t}\left(X_{i,t} = 0, X_{i,t-1} = 0, \left(X_{i,t-1}\right)_{l=2}^{L}\right) \mid X_{i,t} = 1, X_{i,t-1} = 0\}\right]$$

PanelMatch relaxes the unconfoundedness assumption but, as with TWFE, assumes a parallel trend in the outcome variable after conditioning on the treatment, outcome, and covariate histories.

Given set values of F and L, matched sets were created for each treatment group county where each control group county in the set has the same treatment history as the treated county. These matched sets only included observations from the same time period. For example, the control group county observations constituting the matched set for a treatment group county eligible for LFP payments in 2016 were also from 2016. More formally, the matched set for the i^{th} treatment group county in year t, $M_{i,t}$, is defined as:

C.4 $$M_{i,t} = \{i' : i' \neq i, \ X_{i',t} = 0, X_{i',t'} = X_{i,t'} \ \forall\, t' = t-1, \ldots, t-L\}$$

The matched set, $M_{i,t}$, is based solely on treatment history. To meet the parallel trends assumption required for the PanelMatch model, further adjustment is useful. Specifically, this report used matching techniques, which are intuitive tools to address selection into treatment and reduce model dependence, to further refine matched sets (Ho et al., 2007; Rubin, 2006). Matching was based on time varying and time invariant covariates. Control group counties in the matched set that were most similar to the treatment group county receive higher weights in the matching routine.

Finally, assuming that the parallel trends assumption held between treatment group counties and control group counterparts within each matched set, PanelMatch estimated a nonparametric generation of the difference-in-differences estimator to ascertain the causal impact of the LFP program. To do so, the model estimated counterfactual outcomes using the refined control groups within each matched set. Standard errors were calculated using bootstrapping methods with 2,000 iterations.

Appendix D: Stocking Impact of Livestock Forage Disaster Program

Table D.1

Stocking Impact of the Livestock Forage Disaster Program (LFP)

Specification	Point estimate	Standard error	P-value	95-percent confidence interval	
A	1.1937619	0.003932687	0.001274298	[0.394971,	1.974508]
B	0.3868482	0.010906945	0.361670813	[-1.7084947,	2.603024]
C	0.648916	0.010897881	0.276413968	[-1.3687283,	2.865514]
D	0.1659829	0.008086424	0.418750486	[-1.5159418,	1.742337]
E	0.3524173	0.006709383	0.300022084	[-0.9643064,	1.648435]
F	0.4740159	0.006666155	0.239038602	[-0.8339906,	1.720359]

Note: Table D.1 presents point estimates, standard errors, P-values, and 95-percent confidence intervals for the results presented in figure 4 of the main text of the report. Point estimates and confidence intervals are expressed in percentage terms using methods outlined in Halvorsen & Palmquist (1980). Mahalanobis distance matching was used to match treatment and control group counties. Specifications A–F correspond to model results using differing covariates to refine matched sets. These sets of covariates are as follows: (A) no matched set refinement; (B) weeks of D1 and D2 drought and county latitude/longitude; (C) weeks of D1 and D2 drought, county latitude/longitude, and county average temperature/precipitation; (D) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, and county soil characteristics; (E) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, percent of hay irrigated, percent of ag land in pasture, and average pasture rental rate; and (F) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, county percent of hay irrigated, county percent of agricultural land in pasture, county average pasture rental rate, county USDA, Risk Management Agency (RMA) Pasture, Rangeland, and Forage (PRF)indemnities, county USDA, Farm Service Agency's (FSA) Noninsured Crop Disaster Assistance Program (NAP) payments for forage losses, county acres of Conservation Reserve Program emergency haying and grazing, and county USDA, FSA Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) payments for livestock and forage transport.

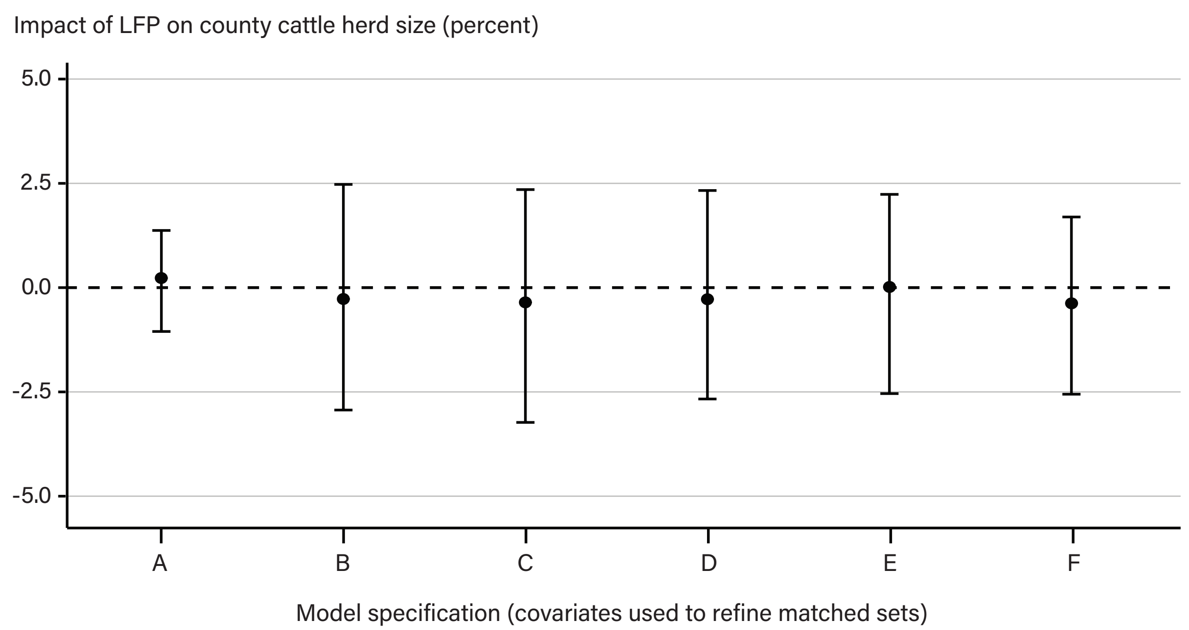
Source: USDA, Economic Research Service using USDA, Farm Service Agency data; and Imai, K. et al. (2021). Matching methods for causal inference with time-series cross-sectional data. *American Journal of Political Science*, 67(3), 587605.

Appendix E: Stocking Impact of Livestock Forage Disaster Program, Percent Change in County-Level Beef Cattle Herd Size as Dependent Variable

The analysis of the Livestock Forage Disaster Program's (LFP) stocking impact in the main text of the report used the log of county-level beef cattle herd size as the outcome variable and then converted estimated impacts into percentage terms. This appendix presents similar results where the outcome variable is the percent change in county-level beef cattle herd size from year-to-year (figure E.1). Figure E.1's differing specifications used the same suite of covariates to refine matched sets as those presented in the main text. Comparing results in figure E.1 to those presented in figure 4 of the main text of the report demonstrates that both modeling approaches yield similar results in terms of the impact of the LFP on subsequent herd stocking decisions, although the estimates in figure E.1 are relatively less precise.

Figure E.1

Causal Impact of Livestock Forage Disaster Program (LFP) payments on county-level beef cattle herd retention liquidation decisions



Note: Figure E.1 plots modeled point estimates (dots) representing the impact of LFP payments on subsequent county-level beef cattle herd size using percent change in beef cattle herd size as the dependent variable. 95-percent confidence intervals are plotted as bars around each point estimate. Mahalanobis distance matching was used to match treatment and control group counties. Differing point estimates (x-axis tick marks A–F) correspond to model specifications that used differing covariates to refine matched sets. These sets of covariates are as follows: (A) no matched set refinement; (B) weeks of D1 and D2 drought and county latitude/longitude; (C) weeks of D1 and D2 drought, county latitude/longitude, and county average temperature/precipitation; (D) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, and county soil characteristics; (E) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, percent of hay irrigated, percent of ag land in pasture, and average pasture rental rate; and (F) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, county percent of hay irrigated, county percent of agricultural land in pasture, county average pasture rental rate, county USDA, Risk Management Agency's (RMA) Pasture, Rangeland, and Forage (PRF) indemnities, county USDA, Farm Service Agency's (FSA) Noninsured Crop Disaster Assistance Program (NAP) payments for forage losses, county acres of Conservation Reserve Program emergency haying and grazing, and county USDA, FSA Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) payments for livestock and forage transport.

Source: USDA, Economic Research Service using USDA, Farm Service Agency data; and Imai, K. et al. (2021). Matching methods for causal inference with time-series cross-sectional data. *American Journal of Political Science*, 67(3), 587605.

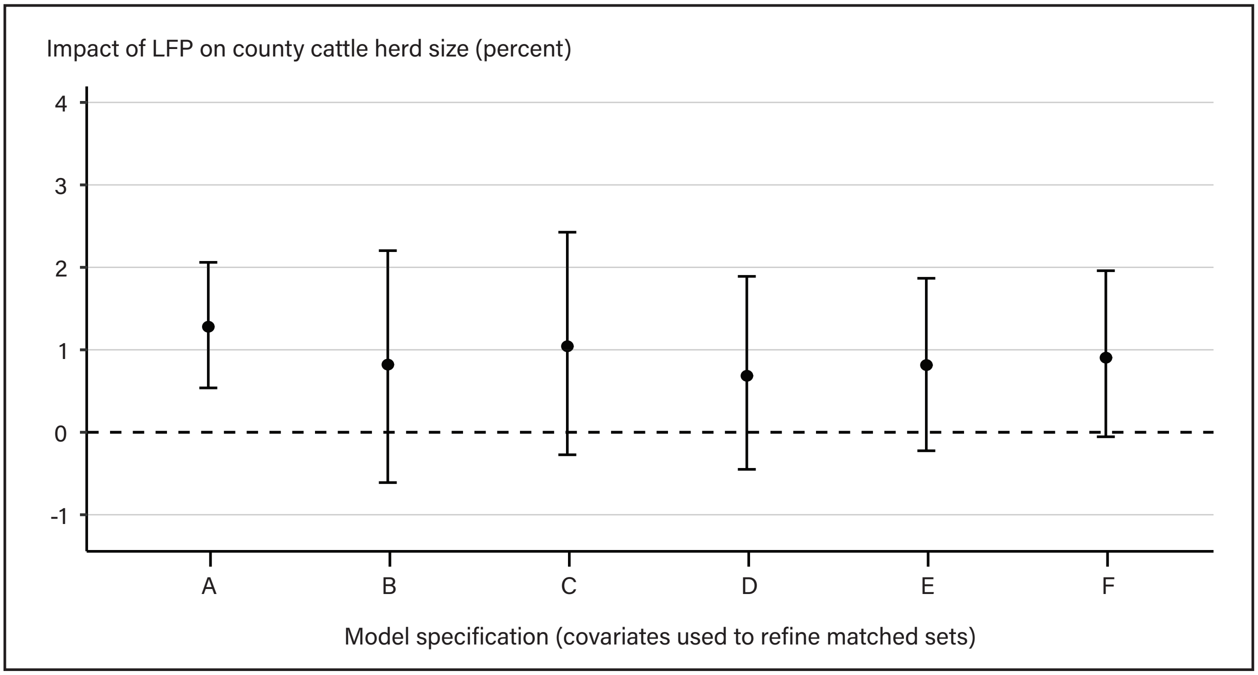
Appendix F: Livestock Forage Disaster Program's Stocking Impact When Treatment Counties Include More Extreme Drought Conditions

This appendix examines whether estimates from the main model specification are sensitive to the definitions of the treatment and control counties. In the main model specification, treatment counties were those that experienced at least 8 weeks of consecutive severe drought (D2) during at least one of their Livestock Forage Disaster Program (LFP) eligible grazing time periods, received 1 month of an LFP payment, and had not experienced any extreme (D3) or exceptional (D4) drought conditions during their eligible grazing period. Control counties were those that experienced at least 1 week of D2 drought during at least one of their LFP eligible grazing periods over the 2014–22 period and received zero LFP payments during the considered year. As a result, counties experiencing more severe drought conditions (D3 and D4) were not considered when estimating the model. Limiting the definition of treated and control counties to D2 exclusively ensured that the estimated impact of LFP relied on county comparisons that experienced similar drought levels.

Figure F.1 shows the LFP program's estimated impact on the log of county-level beef herd size when the definitions of treatment and control are extended to include extreme (D3) drought conditions. Thus, treatment counties were those that had experienced at least 8 weeks of consecutive severe drought (D2) or at least 1 week of extreme drought (D3) during at least one of their LFP eligible grazing time periods, received 1 month or 3 months of LFP payments, and had not experienced 4 or more weeks of extreme drought (D3) or any exceptional (D4) drought conditions during their eligible grazing period (for more information on LFP eligibility, see table 1). Control counties were those that had experienced at least 1 week of D2 drought or at least 1 week of extreme drought (D3) during at least one of their LFP eligible grazing periods over the 2014–22 period and received zero LFP payments during the considered year. In this case, counties that had experienced exceptional drought (D4) were not considered to estimate the model. Results presented in figure F.1 suggest that including counties receiving 1 or 3 months of payments in the treatment group increased the magnitude of the LFP's stocking impact. However, these estimates were relatively unprecise and not statistically significant from 0 except for specification A with no matched set refinement.

Figure F.1

Causal impact of Livestock Forage Disaster Program (LFP) payments on county-level beef cattle herd retention and liquidation decisions



Note: Figure F.1 plots modeled point estimates (dots) representing the LFP payments' impact on subsequent county-level beef cattle herd size. In this specification, those counties that were eligible for 1 or 3 months of LFP payments were considered part of the treatment group of counties. 95-percent confidence intervals were plotted as bars around each point estimate. Point estimates and confidence intervals are expressed in percentage terms using methods outlined in Halvorsen & Palmquist (1980). Mahalanobis distance matching was used to match treatment and control group counties. Differing point estimates (x-axis tick marks A–F) corresponded to model specifications that used differing covariates to refine matched sets. These sets of covariates are as follows: (A) no matched set refinement; (B) weeks of D1 and D2 drought and county latitude/longitude; (C) weeks of D1 and D2 drought, county latitude/longitude, and county average temperature/precipitation; (D) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, and county soil characteristics; E) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, percent of hay irrigated, percent of ag land in pasture, and average pasture rental rate; and (F) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, county percent of hay irrigated, county percent of agricultural land in pasture, county average pasture rental rate, county USDA, Risk Management Agency's (RMA) Pasture, Rangelands, and Forage (PRF) indemnities, county USDA, Farm Service Agency's (FSA) Noninsured Crop Disaster Assistance Program (NAP) payments for forage losses, county acres of Conservation Reserve Program emergency haying and grazing, and county USDA, FSA Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) payments for livestock and forage transport.

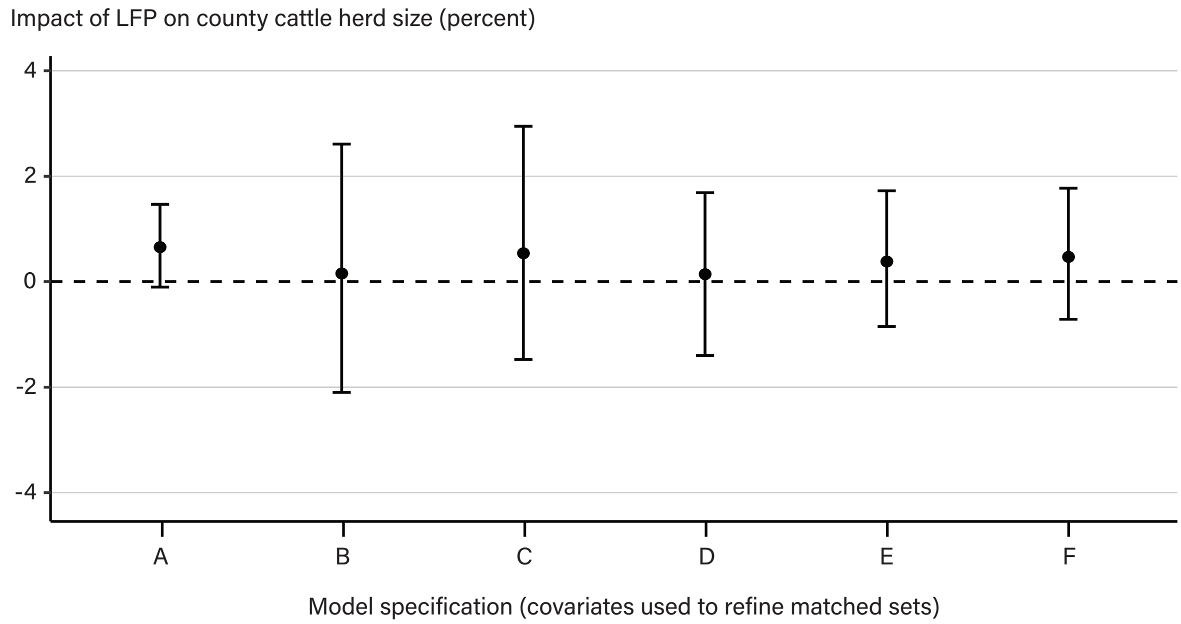
Source: USDA, Economic Research Service using USDA, Farm Service Agency data; and Imai, K. et al. (2021). Matching methods for causal inference with time-series cross-sectional data. *American Journal of Political Science,* 67(3), 587605.

Appendix G: Stocking Impact of the Livestock Forage Disaster Program When Excluding Counties With Large Inventories of Cattle on Feed

This appendix examines how the population of cattle on feed within a given county changes the estimated LFP stocking impacts. County-level data from the USDA, National Agricultural Statistics Service (NASS) Cattle Inventory survey only differentiates cattle based on their use (i.e., beef or dairy) (USDA, NASS, 2023a). The data do not distinguish between grazed beef cattle and beef cattle on feed. Only beef cattle that received the majority of their caloric needs from grazing are eligible for LFP payments. As such, the outcome variable used in the analysis in the main text included counts of some cattle on feed that are not eligible for LFP payments, which could potentially introduce some variation in the analysis. This appendix analyzes whether this inclusion of cattle on feed altered the estimated LFP stocking impact. To do so, this reported leveraged data from USDA, NASS' 2017 Census of Agriculture regarding the count of cattle on feed by county and limited the analysis to only counties where cattle on feed accounted for less than 50 percent of the county's average total beef cattle inventory between 2014 and 2022 (USDA, NASS, 2017). These modeling results demonstrate that the estimated LFP stocking impact on subsequent beef cattle herd retention and liquidation decisions do not differ significantly when excluding counties with a large proportion of beef cattle on feed (figure G.1).

Figure G.1.

Causal impact of LFP payments on subsequent county-level beef cattle herd retention and liquidation decisions excluding counties where cattle on feed account for more than 50 percent of the average total beef cattle herd, 2014–22



Note: Figure G.1 plots modeled point estimates (dots) representing the LFP payments' impact on subsequent county-level beef cattle herd size excluding counties where more than 50 percent of the total average county-level beef cattle herd between 2014 and 2017 are cattle on feed according to data reported in the 2017 Census of Agriculture (USDA, National Agricultural Statistics Service (NASS), 2017). 95-percent confidence intervals were plotted as bars around each point estimate. Point estimates and confidence intervals are expressed in percentage terms using methods outlined in Halvorsen & Palmquist (1980). Mahalanobis distance matching was used to match treatment and control group counties. Differing point estimates (x-axis tick marks A–F) correspond to model specifications that use differing covariates to refine matched sets. These sets of covariates are as follows: (A) no matched set refinement; (B) weeks of D1 and D2 drought and county latitude/longitude; (C) weeks of D1 and D2 drought, county latitude/longitude, and county average temperature/precipitation; (D) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, and county soil characteristics; E) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, percent of hay irrigated, percent of agricultural land in pasture, and average pasture rental rate; and (F) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, county percent of hay irrigated, county percent of agricultural land in pasture, county average pasture rental rate, county USDA, Risk Management Agency's (RMA) Pasture, Rangeland, and Forage (PRF) indemnities, county USDA, Farm Service Agency's (FSA) Noninsured Crop Disaster Assistance Program (NAP) payments for forage losses, county acres of Conservation Reserve Program emergency haying and grazing, and county USDA, FSA Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) payments for livestock and forage transport.

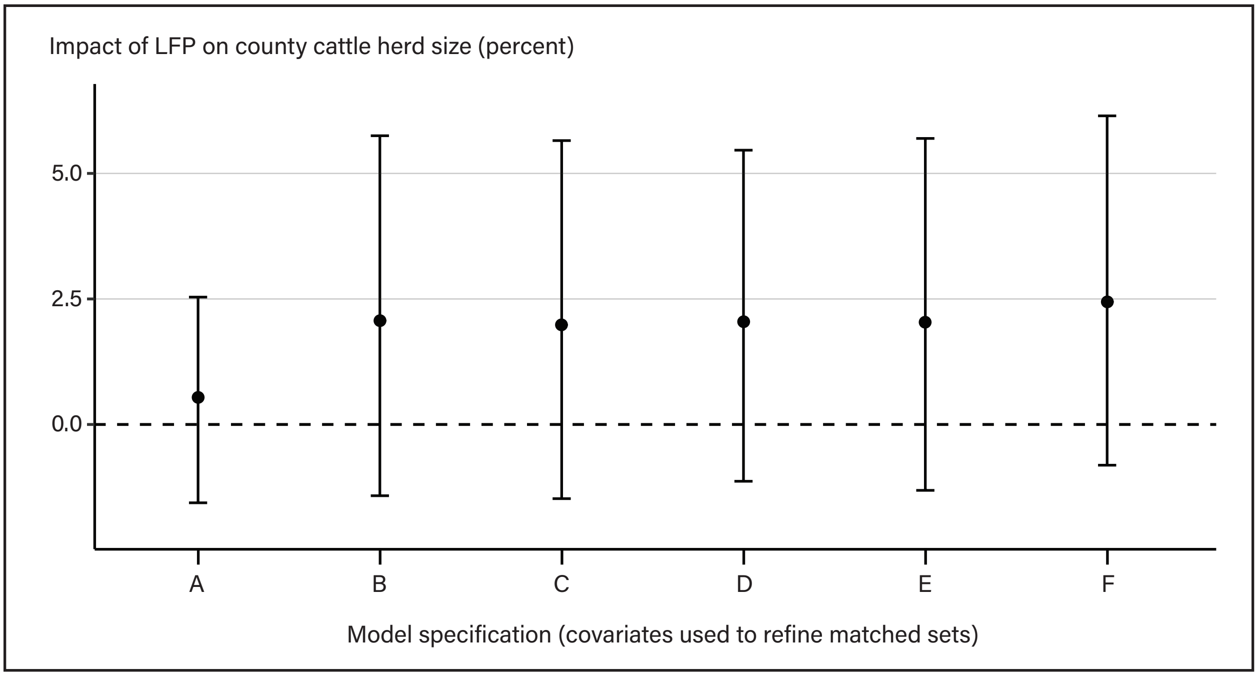
Source: USDA, Economic Research Service using USDA, Farm Service Agency data; and Imai, K. et al. (2021). Matching methods for causal inference with time-series cross-sectional data. *American Journal of Political Science*, 67(3), 587605.

Appendix H: Stocking Impact of the Livestock Forage Disaster Program When Splitting Sample Based on Differing Payment Cap Regimes

The stocking impact analysis presented in the main text of the report examined the Livestock Forage Disaster Program's (LFP) impact on beef cattle herd retention and liquidation decisions during the 2014–22 period. However, as mentioned in footnote 9, payments caps for LFP changed during that period. Before 2019, LFP payment constraints (i.e., a maximum of $125,000 could be paid to a livestock producer) were based on the combination of both LFP payments and other USDA program payments. For example, in 2018 the $125,000 cap applied to the combination of LFP and Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) payments. Between 2012 and 2017, the $125,000 cap applied to the combination of LFP, the Livestock Indemnity Program (LIP), and ELAP. Between 2008 and 2011, the $125,000 cap applied to LFP, the Livestock Indemnity Program (LIP), and ELAP. This appendix explores whether these changes in payment caps over time have had any discernible effect on the estimated LFP's stocking impact by splitting the sample used to estimate these effects into two samples wherein payment caps remained constant (2014–17 and 2019–22). The results of these analyses are presented in figures H.1 and H.2, which plot estimated stocking impacts of the LFP based on samples from the 2014–17 and 2019–22 periods, respectively. Results from both models were similar in sign and magnitude but less precise, with larger 95-percent confidence intervals, to that estimated using the full sample of data between 2014 and 2022, which suggested that changes in LFP's payment caps over time did not significantly bias results.

Figure H.1

Causal impact of Livestock Forage Disaster Program (LFP) payments on county-level beef cattle herd retention and liquidation decisions, 2014–17

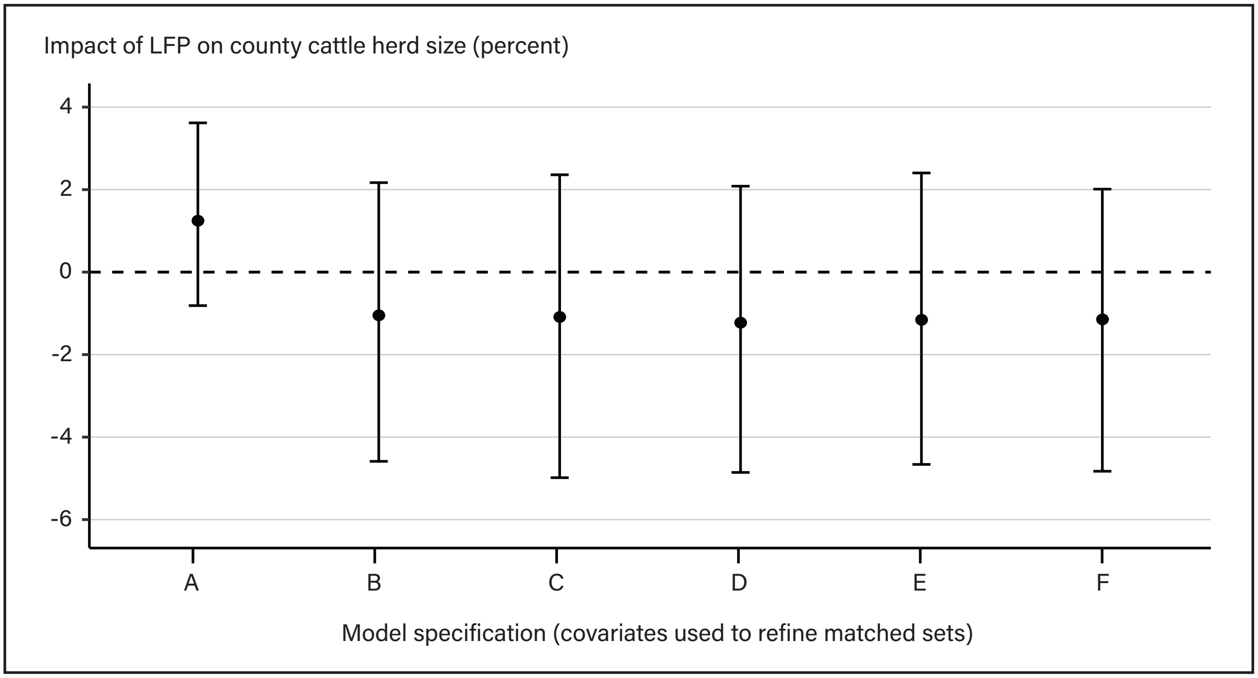


Note: Figure H.1 plots modeled point estimates (dots) representing the LFP payments' impact on subsequent county-level beef cattle herd size only focusing on the 2014–17 period. 95-percent confidence intervals were plotted as bars around each point estimate. Point estimates and confidence intervals are expressed in percentage terms using methods outlined in Halvorsen & Palmquist (1980). Mahalanobis distance matching was used to match treatment and control group counties. Differing point estimates (x-axis tick marks A–F) corresponded to model specifications that used differing covariates to refine matched sets. These sets of covariates are as follows: (A) no matched set refinement; (B) weeks of D1 and D2 drought and county latitude/longitude; (C) weeks of D1 and D2 drought, county latitude/longitude, and county average temperature/precipitation; (D) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, and county soil characteristics; (E) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, percent of hay irrigated, percent of agricultural land in pasture, and average pasture rental rate; and (F) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, county percent of hay irrigated, county percent of agricultural land in pasture, county average pasture rental rate, county USDA, Risk Management Agency's (RMA) PRF indemnities, county USDA, Farm Service Agency's (FSA) Noninsured Crop Disaster Assistance Program (NAP) payments for forage losses, county acres of Conservation Reserve Program emergency haying and grazing, and county USDA, FSA Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) payments for livestock and forage transport.

Source: USDA, Economic Research Service using USDA, Farm Service Agency data; and Imai, K. et al. (2021). Matching methods for causal inference with time-series cross-sectional data. *American Journal of Political Science*, 67(3), 587605.

Figure H.2

Causal impact of Livestock Forage Disaster Program (LFP) payments on county-level beef cattle herd retention and liquidation decisions, 2019–22



Note: Figure H.2 plots modeled point estimates (dots) representing the LFP payments' impact on subsequent county-level beef cattle herd size only focusing on the 2019–22 period. 95-percent confidence intervals were plotted as bars around each point estimate. Point estimates and confidence intervals are expressed in percentage terms using methods outlined in Halvorsen & Palmquist (1980). Mahalanobis distance matching was used to match treatment and control group counties. Differing point estimates (x-axis tick marks A–F) corresponded to model specifications that used differing covariates to refine matched sets. These sets of covariates are as follows: (A) no matched set refinement; (B) weeks of D1 and D2 drought and county latitude/longitude; (C) weeks of D1 and D2 drought, county latitude/longitude, and county average temperature/precipitation; (D) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, and county soil characteristics; (E) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, percent of hay irrigated, percent of agricultural land in pasture, and average pasture rental rate; and (F) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, county percent of hay irrigated, county percent of agricultural land in pasture, county average pasture rental rate, county USDA, Risk Management Agency's (RMA) Pasture, Rangeland, and Forage (PRF) indemnities, county USDA, Farm Service Agency's (FSA) Noninsured Crop Disaster Assistance Program (NAP) payments for forage losses, county acres of Conservation Reserve Program emergency haying and grazing, and county USDA, FSA Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) payments for livestock and forage transport.

Source: USDA, Economic Research Service using USDA, Farm Service Agency data; and Imai, K. et al. (2021). Matching methods for causal inference with time-series cross-sectional data. *American Journal of Political Science*, 67(3), 587605.

Appendix I: Testing the Effectiveness of Matching Methods

The parallel trend assumption required for the PanelMatch model implied that the control and treatment counties were similar across a core set of covariates. The refinement of the matched sets that considered other confounders, such as past outcomes and covariates, helped to meet this assumption and found the most comparable control counties. The resulting covariance balance was assessed during each of the pretreatment periods by calculating the mean of the differences between the covariate values for treated counties and the weighted mean of the control counties across all matched sets (Imai et al., 2021). The results are expressed in standard deviations for each period. This assessment allowed the appropriateness of the parallel trend assumption to be evaluated.

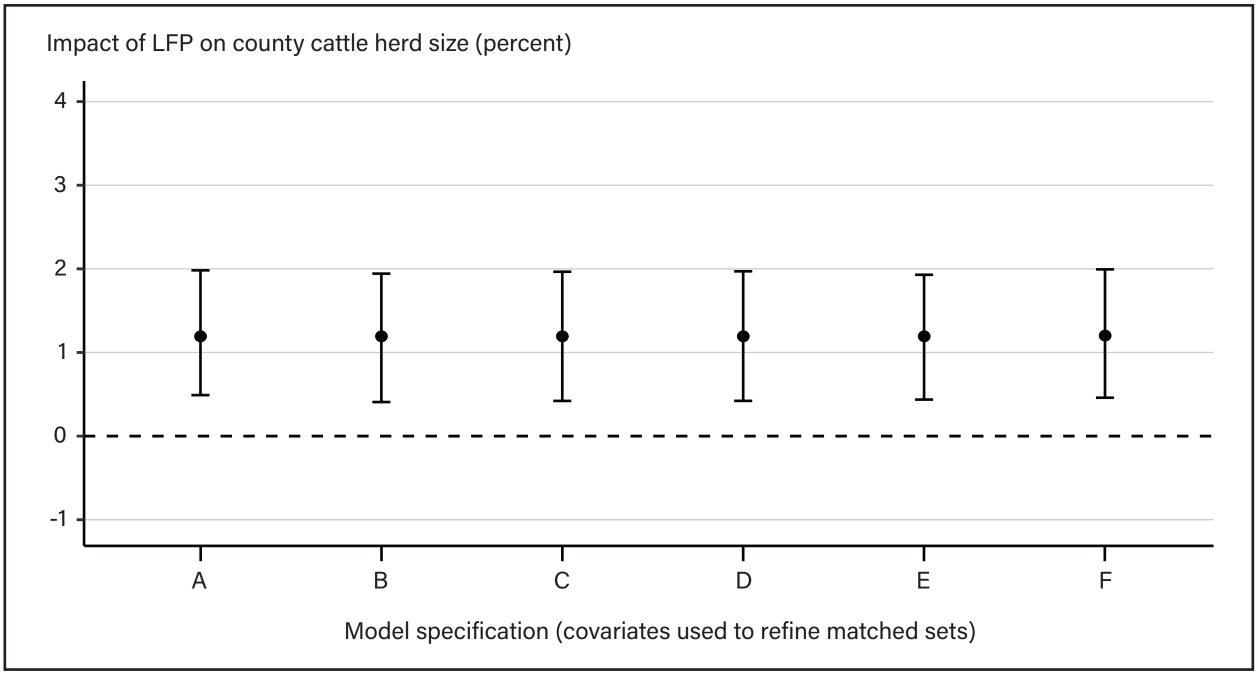
This appendix compares model results for cases where alternative matching methods are employed. The main text of the report used Mahalanobis distance matching (MD). This appendix includes results generated using propensity score matching (PSM) and propensity score weighting (PSW) to refine the matched sets. This inclusion allowed for an assessment of how each refinement method improved the covariate balance between treated and matched control counties. The main difference between these three alternative methods was that MD and PSM selected matched control units within a predetermined matching size. In addition, PSW assigned weights to control units based on their estimated propensity scores ignoring a predetermined matching size (see Imai et al. (2021) for a detailed description).

For each matched control county, the MD computed the standardized Mahalanobis distance using the selected covariates and averaged it across pretreatment periods. Alternatively, PSM used a distance measure based on the estimated propensity score, which is defined as the probability of receiving the treatment given pretreatment covariates. This propensity score was estimated using a logistic regression model that considered all treated counties and their matched control counties from the same year. Because MD and PSM are matching methods, insofar as they only give weights to the most similar control units to each treated units as determined by the distance calculations. That is, the treated counties were matched with their most similar counties based on similarity in control variables. By doing so, these methods selected a subset of control counties from the initial matched set (i.e., before the refinement process) that were most similar to the treated counties in terms of the observed covariates. Lastly, the PSW assigned weights that reflect the inverse propensity score to each control county within a matched set of a given treated county. Unlike MD and PSM, PSW optimized covariate balance by weighting observations independently from a predetermined matching size.

Figures I.1 and I.2 present results of the stocking impact of the LFP using PSM and PSW matching methods, respectively, to assess the robustness of the results of the assessment. PSM yielded significantly different results from those presented in the main text, which used MD. Specifically, the PSM method suggested that LFP does impact subsequent beef cattle herd retention and liquidation decisions. However, recent research by King and Nielsen (2019) questioned the PSM methods' applicability for generating causal estimates of treatment effects as PSM methods can increase imbalance, inefficiency, model dependence, and bias. As such, this report opted to follow recent recommendations in the literature and did not rely on PSM methods for matching as these results may be biased by the matching algorithm. The PSW results were similar to those in the main text in that estimated parameters were not significantly different than zero.

Figure I.1

Causal impact of Livestock Forage Disaster Program (LFP) payments on subsequent county-level beef cattle herd retention liquidation decisions (propensity score matching)

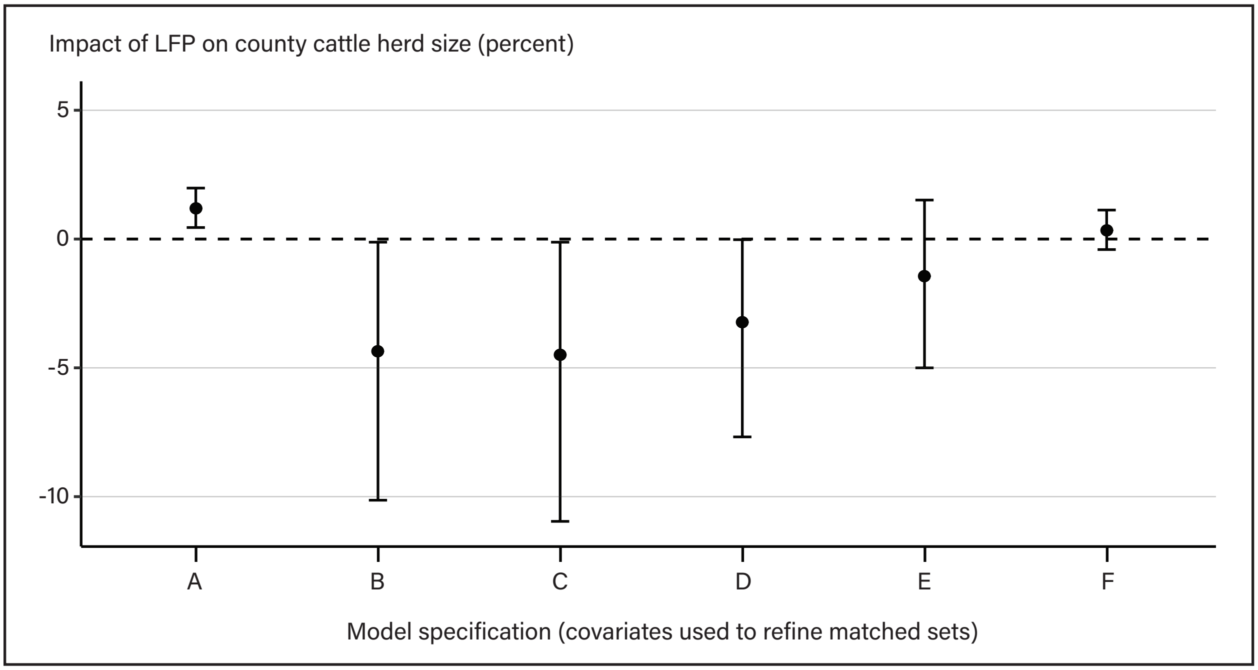


Note: Figure I.1 plots modeled point estimates (dots) representing the impact of LFP payments on subsequent county-level beef cattle herd size. 95-percent confidence intervals were plotted as bars around each point estimate. Point estimates and confidence intervals are expressed in percentage terms using methods outlined in Halvorsen & Palmquist (1980). Propensity score matching was used to match treatment and control group counties. Differing point estimates (x-axis tick marks A–F) corresponded to model specifications that used differing covariates to refine matched sets. These sets of covariates are as follows: (A) no matched set refinement; (B) weeks of D1 and D2 drought and county latitude/longitude; (C) weeks of D1 and D2 drought, county latitude/longitude, and county average temperature/precipitation; (D) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, and county soil characteristics; (E) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, percent of hay irrigated, percent of agricultural land in pasture, and average pasture rental rate; and (F) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, county percent of hay irrigated, county percent of agricultural land in pasture, county average pasture rental rate, county USDA, Risk Management Agency's (RMA) Pasture, Rangeland, and Forage (PRF) indemnities, county USDA, Farm Service Agency's (FSA) Noninsured Crop Disaster Assistance Program (NAP) payments for forage losses, county acres of Conservation Reserve Program emergency haying and grazing, and county USDA, FSA Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) payments for livestock and forage transport.

Source: USDA, Economic Research Service using USDA, Farm Service Agency data; and Imai, K. et al. (2021). Matching methods for causal inference with time-series cross-sectional data. *American Journal of Political Science*, 67(3), 587605.

Figure I.2

Causal impact of Livestock Forage Disaster Program (LFP) payments on subsequent county-level beef cattle herd retention liquidation decisions (propensity score weighted matching)



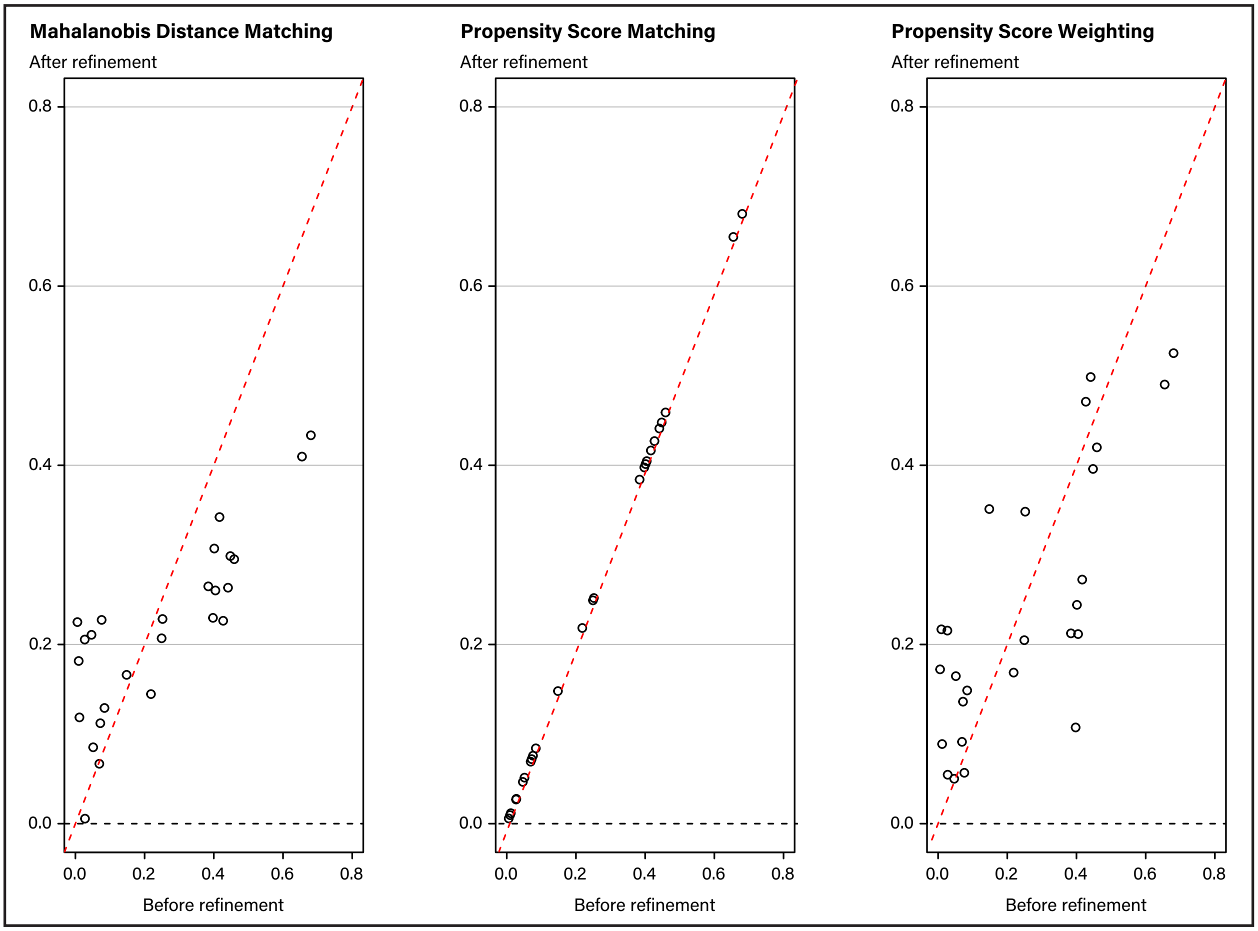
Note: Figure I.2 plots modeled point estimates (dots) representing the impact of LFP payments on subsequent county-level beef cattle herd size. 95-percent confidence intervals were plotted as bars around each point estimate. Point estimates and confidence intervals are expressed in percentage terms using methods outlined in Halvorsen & Palmquist (1980). Propensity score weighted matching was used to match treatment and control group counties. Differing point estimates (x-axis tick marks A–F) corresponded to model specifications that used differing covariates to refine matched sets. These sets of covariates are as follows: (A) no matched set refinement; (B) weeks of D1 and D2 drought and county latitude/longitude; (C) weeks of D1 and D2 drought, county latitude/longitude, and county average temperature/precipitation; (D) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, and county soil characteristics; (E) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, percent of hay irrigated, percent of agricultural land in pasture, and average pasture rental rate; and (F) weeks of D1 and D2 drought, county latitude/longitude, county average temperature/precipitation, county soil characteristics, county percent of hay irrigated, county percent of agricultural land in pasture, county average pasture rental rate, county USDA, Risk Management Agency's (RMA) Pasture, Rangeland,, and Forage (PRF) indemnities, county USDA, Farm Service Agency's (FSA) Noninsured Crop Disaster Assistance Program (NAP) payments for forage losses, county acres of Conservation Reserve Program emergency haying and grazing, and county USDA, FSA Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) payments for livestock and forage transport.

Source: USDA, Economic Research Service using USDA, Farm Service Agency data; and Imai, K. et al. (2021). Matching methods for causal inference with time-series cross-sectional data. *American Journal of Political Science*, 67(3), 587605.

Figure I.3 shows how the refinement of matched sets improved the covariate balance for each matching approach. Each scatter plot presents the absolute value of the standardized mean difference for each covariate before and after the refinement of matched set. The x-axes in figure I.3. are the standardize mean difference between treatment counties and control group counties in the matched set prior to refinement. The y-axes in figure I.3. are the standardize mean difference between treatment counties and control group counties in the matched set after refinement. A 45-degree line is drawn in each plot of figure I.3 to aid comparison between matching algorithms in their ability to improve covariate balance. Points below the 45-degree line in each plot of figure I.3 indicate that the standardized mean difference between treatment counties and control group counties in matched sets decreased after refinement. This indicates that covariate balance between treatment and control group counties was improved after refinement. Points above the 45-degree line in each plot of figure I.3 indicate that the standardized mean difference between treatment counties and control group counties in matched sets increased after refinement. This indicates that covariate balance between treatment and control group counties became worse after refinement. The MD matching shows the greatest level of improvement since most of the dots are below the 45-degree line, which indicates that the standardized mean balance was improved after the refinement for almost all of the covariates. A worse performance was obtained when using PSW (i.e., several dots were plotted above the 45-degree line) and can be explained by the fact that this method assigns weights to the entire sample of treated and control counties, ignoring a predetermined matching size and allowing all counties to contribute to the analysis. Thus, treated counties were not necessarily matched with their most similar controls.

Figure I.3

Absolute value of standardized mean difference for covariates before and after matching refinement



Note: The x-axes in figure I.3 are the standardize mean difference between treatment counties and control group counties in the matched set prior to refinement. The y-axes in figure I.3. are the standardize mean difference between treatment counties and control group counties in the matched set after refinement. A 45-degree line is drawn in each plot of figure I.3 to aid comparison between matching algorithms in their ability to improve covariate balance. Points below the 45-degree line in each plot of figure I.3 indicate that the standardized mean difference between treatment counties and control group counties in matched sets decreased after refinement. This indicates that covariate balance between treatment and control group counties was improved after refinement. Points above the 45-degree line in each plot of figure I.3 indicate that the standardized mean difference between treatment counties and control group counties in matched sets increased after refinement. This indicates that covariate balance between treatment and control group counties became worse after refinement. The MD matching shows the greatest level of improvement since most of the dots are below the 45-degree line, which indicates that the standardized mean balance was improved after the refinement for almost all of the covariates. A worse performance was obtained when using PSW (i.e., several dots were plotted above the 45-degree line) and can be explained by the fact that this method assigns weights to the entire sample of treated and control counties, ignoring a predetermined matching size and allowing all counties to contribute to the analysis. Thus, treated counties were not necessarily matched with their most similar controls.

Source: USDA, Economic Research Service using USDA, Farm Service Agency data; and Imai, K. et al. (2021). Matching methods for causal inference with time-series cross-sectional data. *American Journal of Political Science*, 67(3), 587605.

Appendix J: Modeling the Financial-Climate Risk of the Livestock Forage Disaster Program (LFP)

To model the impact of drought on LFP payments, the report leveraged a panel data econometric model to estimate how an additional month of eligibility for LFP translated into increased program expenditures. Specifically, the model is estimated as follows:

J.1 $$Y_{i,t} = \beta_1 LFP\ Months_{i,t} + \beta_2 Beef\ Cattle_{i,t} + \beta_3(LFP\ Months_{i,t}\ X\ Beef\ Cattle_{i,t}) + \beta_4 Dairy\ Cattle_{i,t} + \beta_5(LFP\ Months_{i,t}\ X\ Dairy\ Cattle_{i,t}) + \beta_6 Sheep_{i,2017} + \beta_7(LFP\ Months_{i,t}\ X\ Sheep_{i,2017}) + \beta_8 Goats_{i,t} + \beta_9(LFP\ Months_{i,t}\ X\ Goats_{i,2017}) + \beta_{10} Equine_{i,2017} + \beta_{11}(LFP\ Months_{i,t}\ X\ Equine_{i,2017}) + \delta_t + \varepsilon_{i,t}$$

Where $Y_{i,t}$ represents the total LFP payments made to livestock producers in county *i* in time *t*. $Y_{i,t}$ is modeled as a function of the number of months of LFP payments livestock producers in county *i* were eligible to receive in time *t* ($LPF\ Months_{i,t}$), and separate variables accounting for the number of beef cattle, dairy cattle, sheep, goats, and equine species (i.e., donkey, burros, horses, mules, and ponies) in county *i* during time *t* as well as interactions between each of these livestock herd size variables and $LPF\ Months_{i,t}$ (for example, $LFP\ Months_{i,t}\ X\ Beef\ Cattle_{i,t}$ represents the interaction between the count of beef cattle in a given county and the months LPF eligibility), a year fixed effect (δ_t), and an idiosyncratic error term ($\varepsilon_{i,t}$). The estimated parameter β_1 represents the marginal impact of an additional month of LFP payments on total county-level payments conditional on the number of cattle within county *i*. Similarly, the parameters $\beta_2, \beta_4, \beta_6, \beta_8$ and β_{10} represent the marginal impact of additional head of livestock on total county-level LFP payments, which are conditional on the number of months of LFP payments producers in county *i* were eligible to receive. Finally, the parameters $\beta_3, \beta_5, \beta_7, \beta_9$ and β_{11} depict how the relationship between months of eligibility and total payments differ as a function of the number of differing types of livestock in county *i.* Including this interaction term was important as LFP payments were made on a per-head of livestock basis (i.e., the relationship between months of LFP payments and total payments depends on the number of livestock within county *i*). The parameters $\beta_3, \beta_5, \beta_7, \beta_9$ and β_{11} capture this relationship by accounting for the impact of a higher county-level herd size on the marginal impact of an additional month of LFP eligibility. δ_t accounts for any common shocks within a given year (i.e., market conditions, cattle cycle, etc.).

The model outlined in equation J.1 was estimated using data collected from a variety of public and administrative sources. The outcome variable, county-level annual LFP payments between 2014 and 2022, were obtained from USDA, Farm Service Agency (FSA) based on their administrative records. Months of LFP eligibility were calculated by joining LFP eligible grazing periods to drought severity data reported by the U.S. Drought Monitor for the 2014–22 period. Finally, species-specific livestock herd size variables for sheep, goats, and equine species came from USDA, National Agricultural Statistics Service's (NASS) 2017 Census of Agriculture and were time invariant in the model. Beef and dairy cattle herd size were time variant and drawn from USDA, NASS' Cattle Survey. Results of the model outlined in equation J.1 are presented in table J.1.

Table J.1

Modeling results: Relationship between Livestock Forage Disaster Program (LFP) payments and drought

	Dependent variable:
	LFP payments (2022 dollars)
LFP months (months of eligibility)	207,099.200***
	(10,206.270)
Beef cattle (number of head)	1.596***
	(0.191)
Beef cattle x LFP months	11.753***
	(0.775)
Dairy cattle (number of head)	0.127
	(0.185)
Dairy cattle x LFP months	-1.069***
	(0.296)
Sheep (number of head)	0.823
	(0.746)
Sheep x LFP months	1.429**
	(0.702)
Goats (number of head)	1.368
	(1.263)
Goats x LFP months	-0.169
	(1.377)
Equine (number of head)	43.793***
	(11.439)
Equine x LFP months	-35.040*
	(18.007)
Observations	28,065
R2	0.469
Adjusted R^2	0.469
Residual standard error	576,532.900 (df = 28,045)

Note: Observations refers to the number of observations used in the regression analysis. R^2 is a statistical measure that represents the proportion of the variance for a dependent variable that is explained by the independent variables within the regression model. Adjusted R^2 is a modified version of the R^2 statistical measure but is adjusted for the number of independent variables within the model. The residual standard error is the standard deviations of the model's residuals. DF stands for degrees of freedom which is the maximum number of independent variables which may vary in a sample of data. Stars (*) represent the level of statistical significance for each model parameter estimate based on differing p-value criteria. The p-value is the probability of obtaining results at least as extreme as the observed results of a statistical hypothesis test, assuming that the null hypothesis is correct. In the context of this table, p-values refer to the null hypothesis that a given estimated parameter is equal to zero. Smaller p-values indicate that there is stronger evidence in favor of the alternative hypothesis, which in this context is that a given parameter estimate is not equal to zero. One star (*) indicates that a given parameter estimate rejects the null hypothesis (that the parameter is equal to zero) in favor of the alternative hypothesis (that the parameter is not equal to zero) for $p = 0.05$. Two stars (**) indicate that a given parameter estimate rejects the null hypothesis (that the parameter is equal to zero) in favor of the alternative hypothesis (that the parameter is not equal to zero) for $p = 0.01$. Three stars (***) indicate that a given parameter estimate rejects the null hypothesis (that the parameter is equal to zero) in favor of the alternative hypothesis (that the parameter is not equal to zero) for $p = 0.001$. Equine species refer to horses, ponies, mules, donkeys, and burros. Parameter estimates such as Beef cattle x LFP months and Sheep x LFP months represent interaction terms between two variables. These interaction term parameter estimates represent the marginal impact of an additional month of LFP eligibility conditional on a given quantity of a specific livestock species on county LFP payments.

Source: USDA, Economic Research Service using USDA, National Agricultural Statistics Service (NASS) *Census of agriculture* (2017) data; USDA, NASS *Cattle inventory* (2023a); and USDA, Farm Service Agency data.

The parameters estimated by the panel data model were used to predict county-level LFP payments under differing projections of drought conditions that influenced the number of months livestock producers were eligible to receive of LFP payments. Specifically, for the i county in future time period t, predicted LFP payments, $\hat{Y}_{i,t}$, are as follows:

$$\text{J.2} \quad \hat{Y}_{i,t} = \hat{\beta}_1 LFP\ Months(Climate\ Scenario_{i,j,t}) + \hat{\beta}_2 Beef\ Cattle_{i,2022} + \hat{\beta}_3(LFP\ Months(Climate\ Scenario_{i,j,t})\ X\ Beef\ Cattle_{i,2022}) + \hat{\beta}_4\ Dairy\ Cattle_{i,2022} + \hat{\beta}_5(LFP\ Months(Climate\ Scenario_{i,j,t})\ X\ Dairy\ Cattle_{i,2022}) + \hat{\beta}_6\ Sheep_{i,2017} + \hat{\beta}_7(LFP\ Months(Climate\ Scenario_{i,j,t})\ X\ Sheep_{i,2017}) + \hat{\beta}_8\ Goats_{i,2017} + \hat{\beta}_9(LFP\ Months(Climate\ Scenario_{i,j,t})\ X\ Goats_{i,2017}) + \hat{\beta}_{10}\ Equine_{i,2017} + \hat{\beta}_{11}(LFP\ Months(Climate\ Scenario_{i,j,t})\ X\ Equine_{i,2017}) +$$

$LFP\ Months(Climate\ Scenario_{i,j,t})$ is a function relating the emission scenario j to the I county's months of LFP eligibility in future time period t. The prediction model used these estimates of future months of LFP eligibility as well as the parameters estimated by equation B.1 to simulate county-level payments. This approach recognized the important relationship between the quantity of livestock within a given county and the marginal impact of an additional month of LFP eligibility on total LFP county-level payments. The time effect, δ_t, is set to zero in the prediction model, which implicitly assumed that the common shocks experienced between 2014 and 2022 reflect common shocks in the future. This is a strong assumption given the likelihood that common shocks influencing the relationship between months of LFP eligibility and cattle herd size on LFP payments (e.g., market conditions, regulations, LFP policy changes, etc.) may change in the future. However, modeling these changes that depend on political, economic, and climatic factors is outside of the scope of this report. Instead, this analysis assumed that the attributes of LFP (e.g., eligibility criteria) will remain constant in the future.

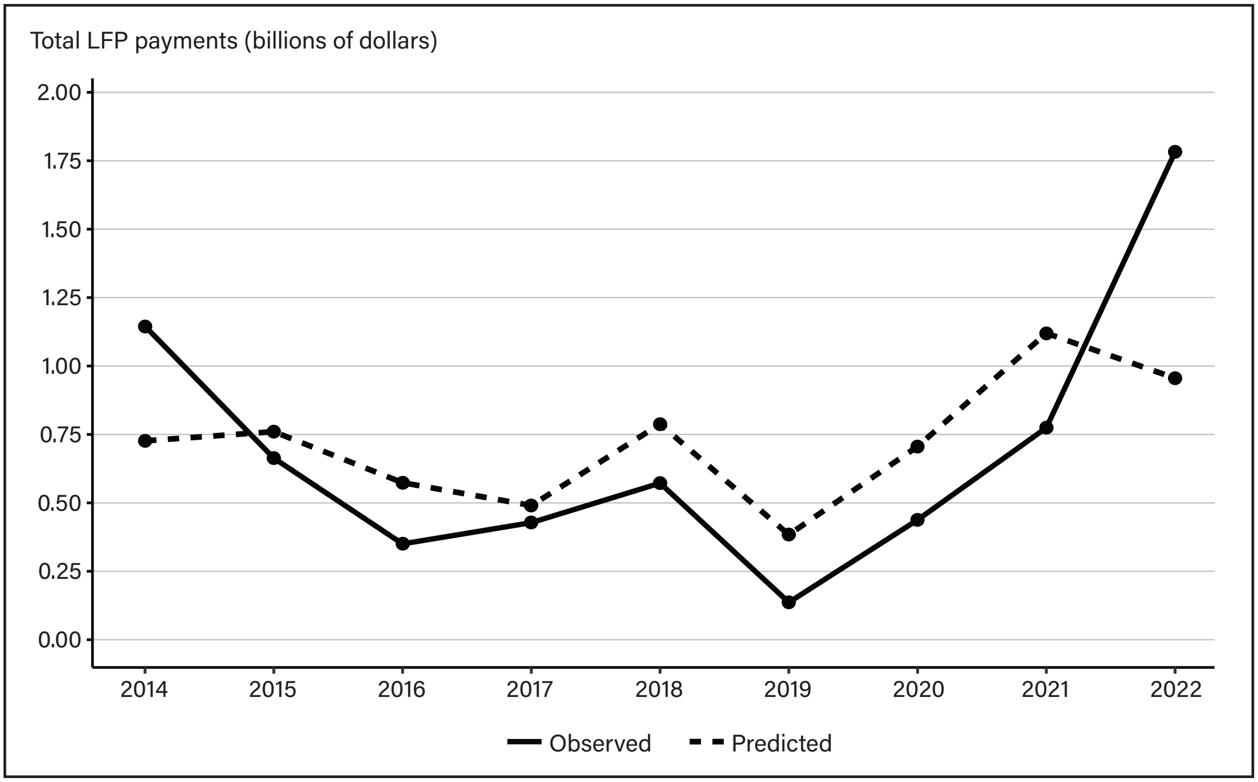
To predict future county-level LFP payments, this report used months of LFP eligibility projected by an ensemble of climate projection models across differing emission scenarios (see "Emission Scenarios" box). These projected months of eligibility were then joined with the most recent county-level species-specific data on livestock herd size to predict LFP payments. For beef and dairy cattle, these data were from USDA, NASS' 2022 Cattle Survey. For sheep, goats, and equine species these data were from USDA, NASSs 2017 Census of Agriculture. This methodology implicitly assumed that county-level livestock herd sizes will not respond to climatic factors. For example, persistent future drought conditions in a given region may induce adaptation among livestock producers through reductions in their herd size. This model did not account for these adaptations. How the livestock sector will adapt to evolving climate conditions is an important avenue for future research efforts. However, modeling that adaptation lies outside of the scope of this report.

To assess the accuracy of the panel fixed effects model estimates in predicting LFP payments this report compared observed aggregate LFP payments between 2014 and 2022 to predicted payments estimated using the simulation model. Specifically, equation J.2 was used to predict county-level LFP payments between 2014 and 2022. Estimated county-level LFP payments were aggregated annually and plotted in figure J.1 along with the observed annual aggregate payments.

Figure J.1 demonstrates that over the 2014–22 period, the LFP payment prediction model does not consistently overestimate or underestimate aggregate LFP payments. Predicted LFP payments generally follow the LFP payment trends that correlate with drought severity in livestock production areas.

Figure J.1

Observed and predicted annual aggregate Livestock Forage Disaster Program (LFP) payments, 2014–22



Note: This figure plots observed and predicted annual aggregate LPF payments between 2014 and 2022. Predicted annual aggregate LFP payments were generated using output from a panel data model estimating the relationship between annual county-level LFP payments and the number of months of LFP payments livestock producers in each county were eligible to receive; the counts of livestock within the county by type (beef/dairy cattle, sheep, goats, and equine species (i.e., horses, ponies, mules, donkeys, and burros); and an interaction between livestock count variables and months of payments. When predicting LFP payments between 2014 and 2022, the estimated time effect, δ_t, was not incorporated.

Source: USDA, Economic Research Service using USDA, Farm Service Agency data; and parameter estimates generated by econometric modeling.

Appendix K: Projections of Future Drought Conditions

To predict future drought conditions under differing emission scenarios and drought classification methods, this report leveraged output from a suite of climate projection models to predict future U.S. Drought Monitor (USDM) drought classifications through 2100 for a range of emission scenarios. The process described below was conducted for each of the emission scenarios considered in this report.

The process of predicting future drought conditions began with calculating daily reference evapotranspiration (ETr) for grass (i.e., forage) using the Penman Monteith method (Zotarelli et al., 2010). Estimated ETr was then joined to output from the suite of climate models on daily precipitation through 2100 to calculate water balance as precipitation (P) excluding ETr (i.e., water balance = P – ETr). These daily observations of water balance were then aggregated over 30-, 60-, and 90-day timescales and the Generalized Logistic (GLO) distribution parameters. These aggregations were estimated over the period of record (POR), which have incorporated climatic data from 1951 onward and 30-year running climatologies using L-moments (Hosking, 1990; Vicente-Serrano et al., 2010).

Water balance aggregations and their estimated distribution parameters were translated into a Standardized Precipitation-Evapotranspiration Index (SPEI) by projecting quantiles into a normalized distribution (i.e., normalizing each distribution). SPEI was then downscaled to short-term blends by averaging across 30-, 60-, and 90-day timescales. The short-term SPEI values were classified into USDM probabilistic classifications using thresholds reported by USDM associating given drought classifications with values of SPEI. Specifically, this report used the following SPEI ranges and probability classifications to translate SPEI to USDM categories.

- D4 (exceptional drought): Less than or equal to 2 percent (equivalent to SPEI less than or equal to -2.054)
- D3 (extreme drought): Greater than 2 percent and less than or equal to 5 percent (SPEI greater than -2.054 and less than or equal to -1.645)
- D2 (severe drought): Greater than 5 percent and less than or equal to 10 percent (SPEI greater than -1.645 and less than or equal to -1.282)
- D1 (moderate drought): Greater than 10 percent and less than or equal to 20 percent (SPEI greater than -1.282 and less than or equal to -0.842)
- D0 (abnormally dry): Greater than 20 percent and less than or equal to 30 percent (SPEI greater than -0.842 and less than or equal to -0.524)

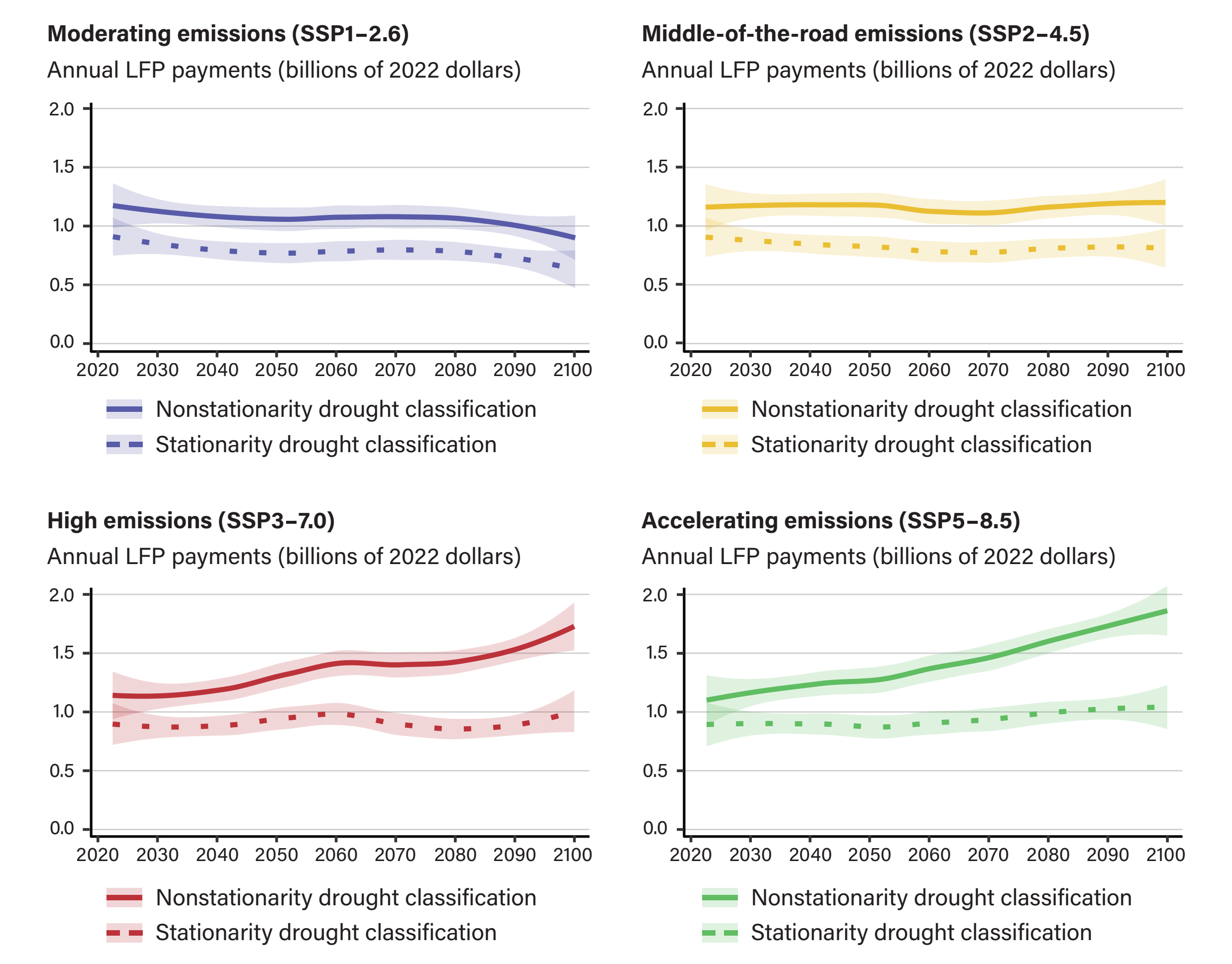
These estimated USDM classifications were then aggregated at the county level, taking the highest (i.e., most severe) drought class per county as LFP eligibility is a function of the most severe drought conditions in a given county. Finally, these USDM classifications were translated into months of county-level LFP eligibility by year for each eligible grazing period and the maximum number of months of LFP payments across all eligible grazing periods was applied to each county-year prediction.

Appendix L: Projections of Future Livestock Forage Disaster Program (LFP) Expenditures by Emission Scenario Differentiating between Stationarity and Nonstationarity Drought Classification

To facilitate comparisons between projected LFP expenditures when classifying drought using stationarity versus nonstationarity methods, this appendix presents results by emission scenario for both the stationarity versus nonstationarity drought classification scenarios. These results are presented below in figure L.1.

Figure L.1

Projected future Livestock Forage Disaster Program (LFP) payments by emission scenario



Note: This figure plots projected annual LFP payments and 95-percent confidence intervals around those projections between 2023 and 2100 for four differing climate change scenarios (see "Climate Change Scenarios" box for more information). Each panel of the figure corresponds to a different emission scenario. Within each scenario, results generated using the current stationarity methods for drought classification. In other words, definitions for drought in a given region are based on 60 or more years of historical climate data are compared with results generated using a nonstationarity method to classify drought (i.e., definitions for drought in a given region are based on 30 years of climatic data and updated through time to reflect a changing climate) (e.g., aridification or humidification). This report considered four different emission scenarios. These scenarios or Shared Socioeconomic Pathways (SSPs) were defined by the Intergovernmental Panel on Climate Change and were designed to span a range of modelled greenhouse gas (GHG) emission scenarios consistent with low to high warming levels (Riahi et al., 2016). Specifically, this report considered the following SSP scenarios: Moderating Emissions (SSP1–2.6): Low GHG emissions, warming is limited to less than 2 °Celsius. Carbon dioxide (CO2) emissions decline to net zero by 2070; Middle of the Road (SS–4.5): Intermediate GHG emissions, warming is limited to less than 3 °Celsius. Carbon dioxide emissions remain around current levels until 2050; High Emissions (SSP3–7.0): High GHG emissions, warming is limited to less than 4 °Celsius. Carbon dioxide emissions approximately double from current levels by 2100; Accelerating Emissions (SSP5–8.5): Very high GHG emissions, warming exceeds 4 °Celsius. Carbon dioxide emissions approximately double from current levels by 2050. Projected future LFP payments were generated using parameter estimates of a panel data econometric model estimating the relationship county-level aggregate annual LFP payments and the number of months of LFP payments producers within the county were eligible to receive. These parameter estimates were then joined to projected future drought conditions in the United States, which distilled future climate conditions into U.S. Drought Monitor classifications and months of LFP eligibility using eight different climate change models (see appendix K for more information). For each climate change model, annual aggregate LFP payments were generated by multiplying econometric model parameters by the number of LFP eligible months projected by the model and summing across counties. Annual results from each climate model were then aggregated and confidence intervals estimated using locally weighted locally weighted scatterplot smoothing (LOESS) regression techniques (Cleveland & Devlin, 1988). Future LFP payments are expressed in real terms (i.e., 2022 dollar values).

Source: USDA, Economic Research Service projections of future drought conditions across differing climate change scenarios and models using USDA, Farm Service Agency data; Imai, K. et al. (2021). Matching methods for causal inference with time-series cross-sectional data. *American Journal of Political Science*, 67(3), 587605.