

DETERMINANTS OF PARTICIPATION AND COVERAGE LEVEL CHOICES IN THE
PASTURE, RANGELAND AND FORAGE INSURANCE PROGRAM

by

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ABSTRACT

Drought risk has become a primary concern for ranchers as a drought can cause substantial financial losses and have been occurring with more regularity and severity than in years past. The Pasture, Rangeland, and Forage (PRF) insurance program allows ranchers to insure their livestock grazing land against potential losses from low rainfall conditions. This program has undergone substantial changes in its availability and premium prices. We implement a linear fixed effect regression model to estimate changes in participation and coverage level choices in response to changes in factors affecting premium payments. Additionally, we analyze the impacts of future prices, previous year's earnings, and the Livestock Forage Disaster Program (LFP) on participation and coverage level choices. Our results show that increasing county base values (CBVs) has a significant negative impact on participation, suggesting the more costly the premium payment, the lower the participation. Additionally, we find evidence of memory anchoring and rational decision making in the purchasing decisions of participants. Overall, we find preliminary evidence that ranchers display demand sensitivity to changes in CBVs as well as evidence that producers follow expected utility theory in choosing the highest coverage levels, especially when coverage levels have the same subsidy rate.

CHAPTER ONE

INTRODUCTION

Not only do ranchers and farmers face financial, market, and policy risks, but additional challenges involve production risks, including weather, disease, and pest difficulties. In the western United States, ranchers frequently experience production losses due to unexpected natural hazards, such as drought. Natural disasters are concerning for ranchers as they may cause sizable financial losses. In the last two decades, the United States Department of Agriculture (USDA) Risk Management Agency (RMA) has created insurance products to try to help agriculture producers with losses attributed to natural disaster risks. One of these products is the Pasture, Rangeland, and Forage (PRF) insurance program, the first program to insure ranchers perennial pasture land against lower than average precipitation.¹

Initially, the PRF program was not widely adopted. However, in the last four years substantial changes have been made to the program and participation has increased rapidly. Since 2016, modifications to the PRF programs county base value (CBV)

¹ Limited policies were available to livestock producers before 2000. This limitation in available policies is likely attributed to a lack of participation in the federal crop insurance program until 1994, when Congress made crop insurance participation mandatory for farmers to eligible for deficiency payments under other support programs, certain loans, and other benefits. Additionally, the Risk Management Agency (RMA) was not developed until 1996. The RMA is responsible for the expansion of agriculture insurance programs, as they have developed programs for agriculture commodities that were not commonly covered by other products (USDA-RMA 2019).

estimations have had considerable impacts on the cost (in terms of premium) and value (in terms of expected indemnity payments) of the insurance program. We exploit that variation in order to make the following contributions. First, this thesis seeks to exploit this variation from changes in CBV to determine whether the implied changes to premiums and expected indemnities influence ranchers' willingness to participate in PRF and their coverage level decisions. Given the large recent changes in CBV calculations and the possibility of future changes, since PRF remains in pilot status, understanding the impact of those changes on the program effectiveness is critical. Second, while most past literature on insurance demand focuses on establishing rates from those participating in insurance programs (and very likely suffering from adverse selection), this study is the first to examine a premium change that is derived from an exogenous entity (weather) and does not rely on the loss history from participation information. This provides the current examination of insurance demand with a clean experimental environment that avoids any adverse selection issues that persists in much of the previous crop insurance literature.

¹Some hypothesize a reduction in indemnity payments could cause a decline in enrollment, especially in areas with the highest enrollment rates (Arizona and New Mexico), as the perception of a reduced indemnity payment can be a reduction in risk

mitigation effectiveness.² While lower CBVs do cause lower potential indemnity payments, they also imply reduced premium payments.³ Lower premiums may be viewed as more affordable to an audience of producers who previously would not enroll. Additionally, producers already enrolling may be able to insure additional acreage or at higher coverage levels and productivity factors for a lower price than in previous years.

Given the program is relatively new, there have been no studies to my knowledge that analyze the impacts of premium and indemnity changes on ranchers' willingness to participate. Of the available literature on the PRF program, topics address charity hazard (Carlson 2017), adverse selection, and basis risk (Nadolnyak and Vedenov 2013; Yu et al. 2019; Williams and Travis 2019). The remaining literature addresses topics comprising of the risk reducing effectiveness of the rainfall index (Maples, Brorsen and Biermacher 2016), optimal interval selection choices (Westerhold et al. 2018; Williams and Travis 2019), the impact of PRF participation on land valuations (Ifft, Wu and Kuethe 2014), and how ranchers respond when receiving an indemnity payment (Shrum et al. 2018).

To measure the impact of CBVs, we implement a least square dummy variable model. To help isolate the effect of the CBV change from changes in premiums, we obtain county premium rates that the RMA uses to calculate the total premium paid.

²Wall Street Journal (2018). "As Ranchers Face Drought, Trump Administration Cuts Back a Critical Program."

³ Premium dollars per acre and premium dollars per liability are illustrated in appendix A.

Additionally, we control for other factors that may influence insurance participation such as previous program experience by using a one-year lagged loss ratio, farm earned income, previous year's drought experience, previous years' experience with the Livestock Forage Disaster Assistance Program, and market price expectations.

We find evidence that reduced CBVs, which effectively lowers premium payments for ranchers, leads to an increase in acres insured. This relationship may be importantly influenced by a ranchers available liquid capital constraint. Therefore, lower CBVs allow ranchers to invest the same amount of money for additional acres. Our results also indicate that producers who are at a higher risk of experiencing losses related to low rainfall are less responsive to changes that impact premium payments and much more likely to insure in the PRF program than lower risk producers.

Additionally, we find evidence participants respond positively to recent loss experience which is a possible indication of memory anchoring. Memory anchoring occurs when individuals use recent events as a reference point to base future decisions. This anchoring bias can lead producers who experience substantial losses in one year to expect the same in the following. On the other hand, it may deter participants from enrolling again if they receive compensation that they perceive to be inadequate for their losses relative to the premium they paid to acquire coverage.

Results from our coverage level analysis do not indicate any statistically significant evidence that PRF program premium price, previous years' losses, earnings, drought condition, LFP participation, or market expectations have an impact on rancher's coverage level choices. Instead, we find ranchers generally enroll in the highest coverage

levels, which provides them with the highest probability of receiving an indemnity.

Additionally, we observe that when coverage levels have the same subsidy rates, ranchers tend to cluster at the higher coverage levels.

As previously mentioned, insurance programs specifically designed for ranchers have historically been limited. The PRF program is the first to insure ranchers' input of perennial forage land, the most common feed source for cattle. An essential step in making the PRF program sustainable is understanding ranchers purchasing decisions and what factors contribute to those decisions. This study provides insight into what factors influence participation and coverage level choices in the PRF program. Currently, the PRF program has the highest participation rates in counties that are at the highest risk of experiencing losses from low precipitation. The findings from this study offer insight for program designers on how to increase and sustain participation to all counties. Additionally, it offers evidence of what will likely occur to participation and coverage level decisions, based on existing patterns, when changes are made that affect the premium payment.

CHAPTER TWO

BACKGROUND

Livestock Production in the Western United States

The western United States provides unique challenges to livestock producers. Much of the available land is unsuitable for farming or any other production given the geographical characteristics. However, one industry that can make use of this land is the livestock industry, who depends on forage as a main feed source. This makes the livestock and forage industry in the western United States closely linked, often thriving or struggling together. In the last two decades, droughts have been occurring with more regularity and severity in western United States (figure 2.1), creating additional challenges to western livestock producers.

A large portion of the western United States is located in high elevations with shallow, rocky soils and rugged terrain. The Rocky Mountains are a key aspect to the region where with most land in elevations above 1000 meters. In addition, most of the west is categorized as being in an arid to semi-arid environment with precipitation levels of less than 20 inches (figure 2.2). The high elevation along with low precipitation create

shorter growing seasons (on average 120 days) leading to limited quantity and quality of forages for livestock (Daly et al. 2008).⁴

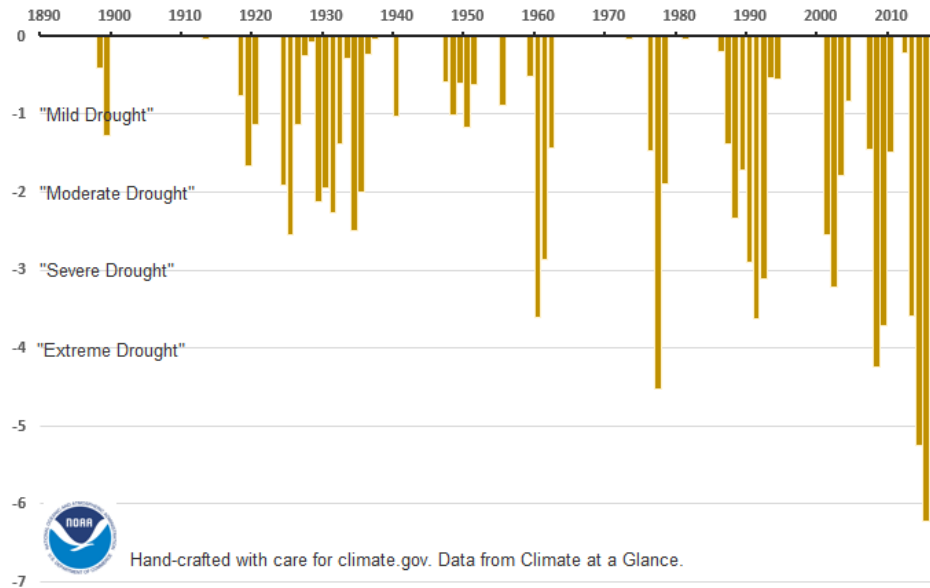


Figure 2.1 Palmer Hydrologic Drought Index for Western United States, 1896 through 2016

SOURCE: National Oceanic and Atmospheric Administration (NOAA)

⁴ Growing seasons are defined by the number of freeze-free days during a year beginning with the last freeze in spring and ending with the first freeze in fall. However recent research has found growing seasons days have been becoming more variable and increasing in recent years (Kunkel et al. 2004; McCabe, Betancourt and Feng 2015)

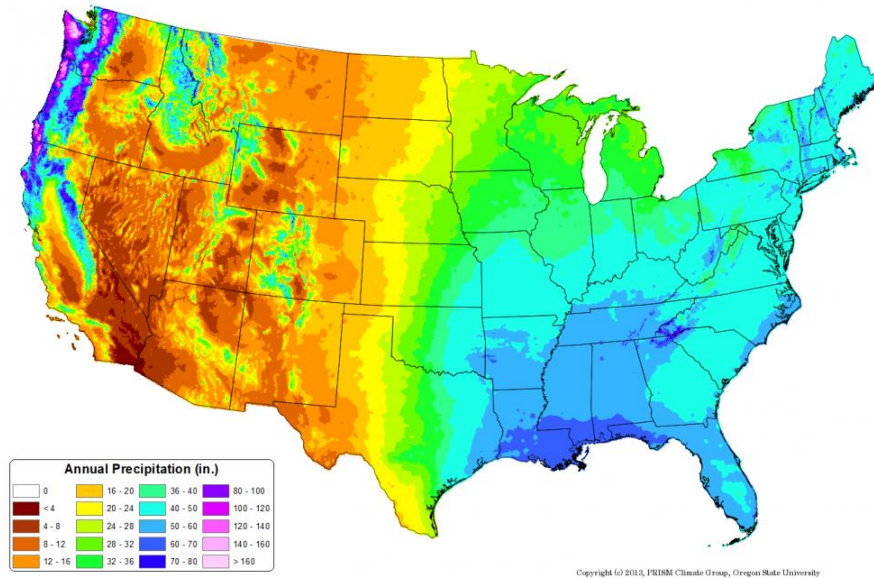


Figure 2.2 United States Precipitation Map
SOURCE: PRISM Climate Group, Oregon State University

Another unique aspect to the western United States is the relatively high portion of federal land (figure 2.3). Federal land is an important aspect of western livestock production as the primary use of forage for cattle and sheep. In the west, an estimated 20% of animal unit months (AUMs) are on public lands and with approximately 60% of cattle production occurring in operations with 100 head or more.⁵ Approximately one-third of forages for larger western livestock production come from federal land (DelCurto, Murphy and Moreaux 2017).

⁵ An animal unit month is the amount of forage required to feed one animal unit (1,000 pound cow and her calf) for one month (Metz 2008).

Currently, the United States has the largest global fed cattle and beef industry with over 20% of this production taking place in the semi-arid western region (USDA-ERS, 2017). For many rural communities within the west, cattle and hay production are important components to their economy. In addition, the Bureau of Land Management (BLM) estimated for the forage year 2012, federal lands contributed 17,000 jobs and nearly \$1.5 billion in economic output (USDOJ 2013).

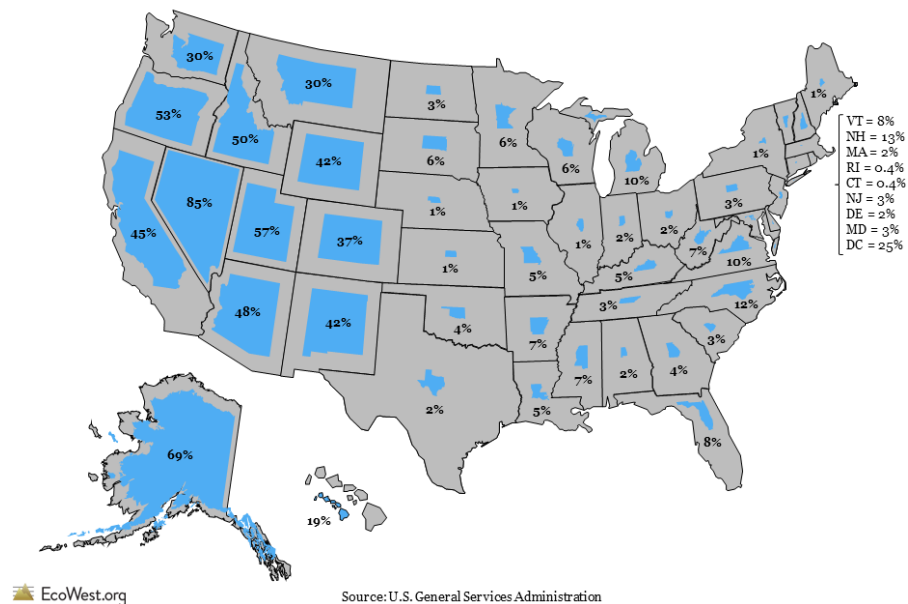


Figure 2.3 United States Portion of Federal Land Map
SOURCE: U.S. General Services Administration

Pasture, Rangeland, and Forage Insurance Pilot Program

Federal agricultural insurance products have been available for over 80 years, covering select major crops (e.g. corn, soybean, wheat). However, participation in the available programs was limited for much of that time. It was not until the mid to late

1990's that these programs began to gain significant interest and enrollment, after approval of increased government paid premium subsidies and requiring farmers to participate in the crop insurance program to be eligible for other loan and price support programs (USDA-RMA 2019). During this period, agriculture insurance and disaster assistance programs expanded to other commodity groups, historically not represented in federal insurance programs. The livestock industry was among these groups, despite contributing approximately half the gross value for the agriculture industry (Koontz 2006). It wasn't until 2000 that the livestock sector was included in federal insurance programs due to the passage of the U.S. Agricultural Risk Protection Act (ARPA). Although some private sector insurance companies did provide livestock products, usually insuring against death losses, the availability of subsidized risk protection for ranchers was limited. Since 2000, insurance products covering livestock inputs and outputs have been developed including the Livestock Risk Protection (LRP), Livestock Gross Margin (LGM), Adjusted Gross Revenue (AGR), Adjusted Gross Revenue-Lite (AGR-Lite), Annual Forage (AF), and the Pasture, Rangeland, and Forage (PRF) programs.

The United States Department of Agriculture (USDA) Risk Management Agency (RMA) developed the PRF Pilot Insurance program in 2007 in response to the growing concern about losses related to more frequent and severe droughts. As a proxy for

drought conditions the product uses a rainfall index.⁶ This product was initially offered only in select states including Montana, California, and parts of Colorado from the western region. Now the program has expanded to all 48 contiguous states.

This program is the first insurance product to assist with livestock producers' perennial grazing and haying acreage, the most common feed source for ruminant livestock. Historically, insurance products offered for livestock protected against animal death losses (offered normally by private insurance companies) and forms of revenue protection (LRP, LGM, AGR, AGR-Lite), but did not cover livestock producers' forages. Now livestock producers may receive risk protection for both annual and perennial acreage, however only perennial risk protection is evaluated in this thesis.⁷

Rainfall and Vegetation Indices

Initially, the PRF program had two index measures for different states that were based on vegetation and rainfall. The vegetation index used the Earth Resources Observation Systems (EROS) Normalized Difference Vegetation Index (NDVI) data that

⁶ The rainfall index is maintained by the National Oceanic and Atmospheric Administrations (NOAA) Climate Prediction Center (CPC) and measures the level of rainfall an area receives during a specified time period relative to a long-term average (also determined by data from NOAA-CPC). A rainfall index is used in index-based insurance products, which indemnify based on deviations from the average of that index rather than the purchaser's own experience. For example, a rainfall index will trigger an indemnity when the rainfall drops below the average for a specified area. It does not indemnify for an individual's reduced yields or prices.

⁷ Perennial forage is insured under PRF and annual forage is insured under AF. Both programs are administered by the USDA-RMA and function similarly by utilizing the rainfall index to base indemnity payments off of. The main difference is simply the crop eligibility under each program.

derives long-term changes in vegetation greenness, measured on a 4.8-mile square grid. When the NDVI measure fell below a pre-determined threshold (an average vegetation greenness), it triggered insurance indemnities. In 2016, the RMA decided to no longer use the vegetation index and switched to solely using the rainfall index in addition to expanding the program to 48 contiguous states.⁸ Under the Rainfall Index-PRF program (RI-PRF), perennial pasture, rangeland and forage intended for grazing livestock can be insured. The RI-PRF uses data from the National Oceanic and Atmospheric Administration Climate Prediction Center (NOAA-CPC) to determine average annual precipitation. The RI-PRF uses a 0.25 degree latitude by 0.25 degree longitude grid (approximately 17 miles x 17 miles at the equator). Indemnity payments are triggered when the interpolated weighted average of rainfall from the closest four reporting NOAA stations falls below the historical average (Maples et al. 2016). The RI-PRF does not rely on production or losses within the area and any losses realized from other drought factors, such as increased wind or warmer temperatures, will not trigger an indemnity payment.

Indemnity Procedure

The RI-PRF program is administered by approved insurance providers (AIPs) and allows livestock producers to select their coverage level, productivity factor, and month

⁸ It is uncertain why the RMA stopped using the vegetation index. However, we assume it is likely attributed to the states using the index having low participation.

intervals insured for their private or public lands. Coverage levels are allowed between 70%-90% in 5 percentage point increments. The U.S. government subsidizes premium rates based on the coverage level. The lowest coverage level (70%) receives the highest subsidy (59%), while the highest coverage level (90%) receives the lowest subsidy (51%). A higher coverage level choice increases premiums and decreases subsidies, but also increases the likelihood of an indemnity payment. The coverage level determines the grid-level precipitation guarantee and the threshold to trigger an indemnity.⁹ The grid is expressed as a percentage with 100 representing the average precipitation over a 75-year period. Below 100 represents below average precipitation, while above 100 represents above average. Indemnity payments are dependent on the degree to which the actual index falls below the historical average. This is used to determine the size of an indemnity (if triggered), called the payment calculation factor (PCF), which is the difference between the guaranteed index selected and the actual index value as a percentage of the guaranteed index value for a particular interval selected i in grid g , but it should be noted that for the purpose of this study we evaluate at the county level rather than the grid:

⁹ Each grid has a pre-determined historical average rainfall threshold. The coverage level determines at what percent of the threshold an indemnity will be triggered, also known as the precipitation guarantee.

$$PCF_{ig} = \begin{cases} \frac{Guarantee\ Index_{ig} - Actual\ Index_{ig}}{Guarantee\ Index_{ig}} & Actual\ Index_{ig} < Guarantee\ Index_{ig} \\ 0 & Actual\ Index_{ig} \geq Guarantee\ Index_{ig} \end{cases} \quad (2.1)$$

Policy holders also select a productivity factor between 60% and 150% of the county's base value (CBV) in 1% increments. This allows producers to determine their insured lands actual productivity and adjust for differences between the estimated county base value. This is used to determine the policies liability (also referred to as “policy protection”), which is the maximum dollar amount paid in the event of a complete loss. The liability for interval i in grid g , represented below on a per acre basis, is calculated by taking the CBV for grid g multiplied by the productivity factor and the guarantee level selected.

$$Liability_{ig} = CBV_i * Productivity\ Factor_i * Guarantee\ Level_{ig} \quad (2.2)$$

Livestock producers cannot insure their acreage for the entire year. Instead, they must select at least two nonconsecutive two-month intervals to insure from the following: January-February, February-March, March-April, April-May, May-June, June-July, July-August, August-September, September-October, October-November, November-December. Producers can select up to six non-consecutive intervals and must determine the proportion of coverage to be allocated to a particular interval with a minimum allocation of 10% to an interval and a maximum between 50-70%, depending on geographic location. Each interval selection can have a different productivity factor and coverage level selection. These decisions are used to determine the indemnity payout if the rainfall index for the grid area g falls below the selected guarantee level during the

selected interval i (USDA-RMA 2017b). The indemnity is comprised of the PCF and liability for grid g during interval i .

$$Indemnity_{ig} = Payment\ Calculation\ Factor_{ig} * Liability_{ig} \quad (2.3)$$

County Base Values

County base values are determined by the RMA, primarily using data from the National Agricultural Statistical Services (NASS), and initially were estimated using a three-year average of state level revenue for grazing and haying practices represented by equation 2.4:

$$County\ Base\ Value = Crop\ Yield * Crop\ Price \quad (2.4)$$

Originally this estimation combined irrigated and non-irrigated production, as well as organic and conventional. Audits made by the USDA have found that CBVs have been disproportionately high in many states, resulting in indemnities in excess of actual losses realized (USDA-Office of Inspector General 2019). In particular, Colorado, New Mexico, and Texas were evaluated, finding producers in Texas able to insure at a maximum of \$223.92 per acre, Colorado at \$478.06, and New Mexico at \$497.03. The audit sampled producers land productivity within these states and found estimation for yield in Colorado and New Mexico were approximately twice the yield capability of the samples. Therefore, they estimate that \$34.5 million in indemnity payments from 2016 to 2018 were based on inflated CBVs.

To account for inconsistent CBVs, the RMA has made several changes since 2016 to more accurately account for diverse growing conditions across states. The RMA

realized that combining irrigated and non-irrigated land in the estimation of CBVs would overestimate non-irrigated lands productivity, as irrigated land can produce significantly higher yields. Therefore, in 2016 irrigated and non-irrigated land was separated in western states' CBV estimation (USDA-Office of Inspector General 2019).

In 2018, the RMA began to estimate CBVs at the sub-state level and incorporated data from the Natural Resource Conservation Service (NRCS) plant productivity model on precipitation, soil, and climate. The introduction of these data provide more accurate estimates for a counties potential productivity. Methods used to estimate irrigation were adjusted to reduce prices in areas that heavily uses irrigation practices, leading to higher quality hay and resulting in higher price estimates. Additionally, organic prices for non-irrigated hay were added to select states including Colorado, Nevada, New Mexico, Oregon, Idaho, Montana, Washington, and Wyoming. As a result of additional data, sub-state analysis, and separate evaluations for growing types the 2018 CBVs for hay acreage decreased in many areas (USDA-RMA 2018). In 2019, the RMA incorporated data on rental rates, grazing fees, and hay prices within the NRCS productivity model to determine grazing yield and price estimates. This caused lower CBV grazing prices to account for the difference in value for pasture and hay. Additionally, organic non-irrigated hay CBVs were added for all western states (USDA-RMA 2019).

CHAPTER THREE

LITERATURE REVIEW

Index-based insurance products have gained traction in the last few decades due to the relative simplicity of the program design, reductions in asymmetric information held by the insured, and the low costs of implementation (Smith and Glauber 2012; Barnett and Mahul 2007). However, index insurance programs also pose unique challenges, mainly from imperfect correlations between indices and production. This variation is referred to as “basis risk” and reduces the programs ability to effectively protect against downside risk. Inefficiencies in risk protection have negative implications for participation within index insurance products. Smith and Watts (2009) determine six factors affecting a person’s decision to enroll in an index program: 1) size of potential loss relative to a person’s wealth, 2) frequency losses occur, 3) severity of actual loss, 4) cost associated with enrolling, 5) how efficient the program is at providing protection when losses incur, and 6) availability of other risk management strategies.

A key aspect in evaluating an index insurance product’s effectiveness is its ability to reduce risk by providing an indemnity payment when losses occur. Smith and Watts (2009) conclude for an index insurance product to be scaled up and to be sustainable there must be a sufficient number of potential users willing to pay for it, it must be affordable, have low levels of basis risk, and it must be accessible with a sufficient amount of infrastructure. Inability to reduce policy holders’ risk leads to reduced participation rates and increases in policyholders exiting the program; this is commonly a result of adverse

selection where the policyholder and the insurer do not have the same level of information (Rothschild and Stiglitz 1976).

A thin literature exists evaluating the PRF pilot insurance program, but several studies address the risk reducing aspects of the program (Nadolnyak and Vedenov 2013; Carlson 2017; Westerhold et al. 2018; Yu et al. 2019). A more common topic of research is the presence of basis risk within the PRF program. Research has found basis risk is nearly unavoidable in index insurance products as they cannot protect against risk caused by any other factor than what the index detects. All basis risk research regarding the PRF find risk associated with low precipitation is highly correlated with indexes used, but for purchasers in areas prone to droughts for other adverse conditions this index lacks correlation with actual losses (Maples et al. 2016; Williams and Travis 2019; Yu et al. 2019). Additionally, the index may not be an appropriate fit for all individuals' situations, even for the factor the index measures. This leads to another concern found within the PRF program—adverse selection. Research finds purchasers may display adverse selection within the PRF program through interval selection (Carlson 2017; Westerhold et al. 2018; Williams and Travis 2019) and/or long-run weather forecasts (Nadolnyak and Vedenov 2013). As adverse selection is predicted to be present in interval selection, a notable amount of research has evaluated the optimal risk reducing interval selections (Carlson 2017; Westerhold et al. 2018).

Although recent literature has mentioned program participation, to the author's knowledge, no work has directly analyzed the determinants of purchasers' decisions to enroll in the PRF program or not. This thesis also makes use of the large changes in

premiums within a program with relatively low participation. Likewise, no research to date has assessed the factors motivating a purchaser's coverage level decisions. This thesis seeks to build upon the existing literature by investigating the primary causes for a purchaser's choice to enroll in the program, as well as their coverage level selection.

Expected Utility Theory

The expected utility theory explains individuals behaviors when making decisions with choices that have uncertain outcomes. Under this theory individuals will always choose the option that will give them the highest expected utility. This behavior has also been explained as the rational choice when faced with uncertainty (Briggs 2019). Some literature attempts to explain crop insurance coverage level choices by using the expected utility theory (Du, Feng and Hennessy 2016). An individual's utility can be affected by multiple factors when choosing a coverage level. The higher the coverage level the greater the probability of triggering an indemnity and potentially a higher indemnity payment. On the other hand, a higher coverage level generally results in a smaller subsidy rate and a greater premium payment. Therefore, Du et al. (2016) explain an individual's coverage level choice will be consistent with the expected utility theory if they pick the highest coverage level that maximizes their per acre premium subsidy payment. However, some studies find this theory to be inconsistent in crop insurance application (Babcock 2015; Bulut 2016).

Prospect Theory

Expected utility maximization theory has generally been used to explain decision making. However it is commonly criticized as not holding for choices made under risk. In particular, individuals tend to overweight outcomes that are certain compared to outcomes that are probable. Kahneman and Tversky (1992) explain this behavior through prospect theory. Prospect theory includes four elements: 1) reference-dependence, 2) loss aversion, 3) diminishing sensitivity, and 4) probability weighting.¹⁰

A small literature exists evaluating index insurance products using prospect theory (e.g. Patt et al. 2009; Carter, Elabed and Serfilippi 2015). Carter et al. (2015) finds index insurance has been viewed as riskier than conventional yield insurance, and often thought of as a gamble. This is because of the presence of basis risk within index insurance programs leading to a weak correlation between the index and actual production. They explain that low participation in index insurance programs can be heavily attributed to this perceived gamble. For highly risk averse purchasers, index

¹⁰ Reference-dependence assumes the value function is a function of a reference point for an asset's starting position and the magnitude of change from that reference point. Loss aversion assumes people are impacted more by losses, even small losses, than compared to gains of the same magnitude. Under the third assumption, people display diminishing sensitivity. Kahneman and Tversky use an example to explain diminishing sensitivity: A person's utility is significantly impacted by replacing a \$100 gain (or loss) by a \$200 gain (or loss), but they experience a smaller impact when a \$1000 gain (or loss) is replaced by a \$1100 gain (or loss). Additionally, the value function is concave in gains and convex in losses. This indicates people are risk averse in gains and risk-seeking in losses. Lastly, prospect theory finds people do not weight outcomes by their objective probability but by decision weights. Decision weights are determined by the relative desirability of prospects; therefore, overweighting is found in low probability outcomes and underweighting in high probability outcomes (Kahneman and Tversky 1979).

insurance would not appeal as there is the possibility of paying a premium, experiencing a loss, and not being indemnified, leaving the purchaser worse off. Ultimately, the higher the basis risk within the index insurance program, the riskier the program is viewed and the less likely a person is willing to purchase coverage (Carter et al. 2015).

Basis Risk

Basis risk is a main concern relating to index insurance products. While yield-based insurance products can be impacted by problems such as moral hazard, index insurance products are often not subject as the indices are exogenous to policyholders behavior and/or characteristics (Barnett, Barrett and Skees 2008). Basis risk occurs when the index used is not representative of a policyholder's actual outcomes. This imprecision can lead to a lack of payments following losses and/or overpayments when little to no loss was realized. There are two main sources of basis risk within the PRF program: "(1) correlation of the index with actual rainfall and (2) correlation of rainfall and forage yields," also referred to as geographic and production basis risk (Maples et al. 2016). Other studies have found that basis risk has a negative impact on participation in index insurance products, as a higher level of basis risk leads to lower correlations between actual yield losses, and thus reducing the effectiveness of the program in protecting against losses (Giné, Townsend and Vickery 2008; Elabed et al. 2013; Clarke 2016; Smith and Watts 2009).

Yu et al. (2019) estimate the amount of basis risk that stems from the RI-PRF insurance program using a linear regression model with historical yield and rainfall data. Their findings indicate basis risk within the PRF is approximately 26%, which Yu et al.

describes as moderate. However, the majority of basis risk within the program can be attributed to factors aside from low precipitation. Actual basis risk attributed to site-level precipitation was estimated at 5-9%. Therefore, they conclude there is a convincing correlation between losses related to low precipitation and suggest utilizing site-level precipitation to trigger indemnities would not result in decreased basis risk. They further recommend the best way to decrease basis risk is by utilizing an index system that more accurately accounts for other factors relating to drought losses (e.g. high wind speeds, high temperatures), aside from precipitation.

Williams and Travis (2019) observe policyholders in the PRF Pilot Program and determine they are exhibiting profit maximizing rather than risk minimizing behaviors in their interval selections. Rather than select the intervals that minimize risk for the policyholders' operations, they insure in months when rainfall is most variable to maximize expected profits. They examine multiple types of drought indices to determine if any would be more efficient in reducing basis. Their results show payments triggered from drought indexes would be more concentrated during growing seasons, which reduces profit maximizing behavior and accounts for the present temporal basis risk. Ultimately, they conclude that utilizing a drought index that accounts for more than reduced precipitation would offer more precise correlations with losses, lowering basis risk.

Maples et al. (2016) analyzed the Rainfall Index Annual Forage Pilot (RIAFP) program, which uses the same RMA rainfall indices as the PRF program to determine indemnities. Using data from a farm in South-Central Oklahoma, the study aims to

determine if the rainfall index provides adequate coverage for the RIAFP. Their results show the rainfall index is highly correlated with actual rainfall, but is not an accurate measure of actual yield loss. This indicates a possible inefficiency in an insurance programs ability to protect against risk. These results raise concern as they may extend to other locations. However, any generalizations should be taken with great caution as these results are limited to the farm and crop examined.

Westerhold et al. (2018) use a modified model from Maples et al. (2016) to focus on the risk reducing aspects of selecting different insurance intervals in the PRF. Using two farm locations in Nebraska, the study finds insuring in high precipitation months, which are historically during the growing seasons, reduces net income risk. Conversely, insuring in low precipitation months (non-growing season) increases net income risk. This indicates a preference may exist to maximize net income over risk minimizing, for some policyholders, by enrolling in expected low precipitation months. This study confirms the findings from Carlson (2017), who found evidence risk was only reduced when historically high precipitation month intervals were selected.

Adverse Selection

Index insurance products are believed to reduce the amount of asymmetric information between insurance providers and purchasers, but they are not completely exempt from the problem. Asymmetric information refers to a circumstance where one party has a greater amount of knowledge regarding a product compared to the other. This is commonly observed in insurance markets when a producer purchases insurance in the case where they know they'll get a payment and does not in other years— because they

have more information than the insurance provider. This undermines the actual effectiveness of index insurance programs, as it increases the long-term loss ratio of the contracts (Just, Calvin and Quiggin 1999).

Limited research has addressed the potential for adverse selection within the PRF program (Nadolnyak and Vedenov 2013; Williams and Travis 2019). Nadolnyak and Vedenov (2013) exploit how climate forecasts can be used by producers' purchasing PRF insurance and could lead to intertemporal adverse selection. Using a stochastic model, they analyze areas in the United States heavily impacted by El Nino Southern Oscillation (ENSO) for producers who may have access to long run ENSO forecasts. Under three different scenarios they find producers with access to long run ENSO forecasts located in areas heavily impacted by ENSOs display intertemporal adverse selection and further suggest the RMA incorporates long run climate forecasts into premium calculations (Nadolnyak and Vedenov 2013).

In addition to the Williams and Travis (2019) findings of temporal basis risk they also find evidence of adverse selection within the PRF. Their analysis finds the least critical months for forage production (winter months) are commonly those that indemnify the most frequently under the rainfall index. Therefore, purchasers are incentivized and commonly found to insure when they believe they are most likely to receive a payment (Williams and Travis 2019).

CHAPTER FOUR

THEORETICAL METHODOLOGY

Agricultural insurance literature has commonly used expected utility (EU) maximization theory to explain farmers' and ranchers' decisions under uncertainty. EU assumes that, under risk neutrality, producers will purchase insurance that maximizes their expected net return, but those predictions may be different if risk tolerances differ (Rothschild and Stiglitz 1976). However, researchers are critical of this framework for being inconsistent with actual agriculture producer decisions. For example, we expect an EU maximizing farmer to insure at the highest coverage level decisions to maximize per acre subsidies, but these results conflict with actual practices (Du et al. 2016). Another example is index insurance products frequently having lower than expected participation rates, likely attributed to the perceived riskiness of the program. In contrast, an EU maximizer would tend to enroll when positive expected returns and lower variance coincide with mitigating any potential risk, as is the case with subsidized insurance (Carter et al. 2015).

Due to EU theory being frequently called into question and ranches being considered firms, it is most appropriate to employ an expected profit maximization framework to examine the effects of changes in the PRF program CBVs with ranchers' coverage and enrollment decisions. Risk preferences are assumed to be risk-neutral in this model as we do not observe these preferences in our empirical model. Equation 4.1 characterizes the expected profit maximization problem of a typical rancher.

$$\pi = \left(E \left[\sum_{t=1}^T P_{it} F(X_{it}, \varepsilon_{it}) + \left(\sum_{s=1}^{s=n} I_{it} [R_t^b, R_t, V_{it}, G_{it}, a_{it}, p_{it}, H_{it}] \right) + \text{LFP}_{it} [D_{it}, J_{it}] \right] \right) - \lambda \left[\left(\sum_{s=1}^{s=n} \theta_{it} [L_{it}, PR_{it}] \right) + \sum_{j=1}^j w_{ijt} X_{ijt} + C_{it} - M_t(\pi_{t-1}, B_t(E_t)) \right]$$

Where $\varepsilon_{it} = (\gamma_{it}, Z_{it})$

Where $L_{it} = (V_{it}, G_{it}, a_{it}, p_{it}, H_{it})$ (4.1)

The rancher's expected profit maximization problem is equal to the difference between revenue and costs from period t to the terminal time T , where E is the expectation operator. Revenue for a rancher is the product of the market price for livestock (P_{it}) for ranch i in time t and the livestock yields represented by $F(\cdot)$, a function of the rancher's inputs (e.g., grain, hay, vaccines, etc.) (X_{it}) and a stochastic element (ε_{it}) characterizing any deviations from yield that are uncontrollable by the rancher. Deviations in livestock yields are split into two categories, attributed to weather conditions (γ_{it}) (which incorporates rainfall level (R_t)) and deviations accredited to uncontrollable health and predation reasons (Z_{it}). Additionally, the PRF program indemnity payments (I_{it}) may increase profits and is a function of expected rainfall (R_t^b ; historical average rainfall over 70 years) and actual rainfall in time t (R_t), as well as the county base value (V_{it}), coverage level selection (G_{it}), percent of land insured under a particular interval selection (H_{it}), productivity factor (p_{it}), and the total number of acres insured (a_{it}).

To receive a PRF indemnity payment, ranchers must incur the cost of a PRF premium payment (θ_{it}). The premium payment is equal to the product of liability (L_{it})

and premium rate (PR_{it}) for each interval selection (denoted by subscript s) chosen by the rancher. A rancher's liability is a function of the county base value (V_{it}), coverage level selected (G_{it}), acres insured (a_{it}), percent of the land insured under a particular interval selection (H_{it}), and productivity factor (p_{it}). Costs include the summation of variable costs and fixed costs, where variable costs comprise of the price of input j associated with the i^{th} rancher at time t (w_{ijt}) and the amount of input j associated with i^{th} rancher (X_{ijt}). Total fixed costs (equipment depreciation, interest on land, property tax, etc.) are represented by C_{it} for the i^{th} rancher at time t .

Ranchers also face a liquidity constraint of the previous year's profits to purchase PRF insurance in the current year. In the constraint, the profit maximization equation is subject to available credit, where all costs must be covered by the available liquid capital the ranch has at its disposal using the previous year's profits or capital borrowed. The constraint is represented by $M_t(\pi_{t-1}, B_t(E_t))$, where M_t is liquid assets as a function of the last year's profit and the amount the rancher is willing or able to borrow against their equity $B_t(E_t)$.

We also consider the impact of other programs such as the LFP program, that cover related risks. A rancher may be eligible for LFP payments (LFP_{it}), which are a function of the drought severity (D_{it}) and estimated feed costs (J_{it}). Previous literature finds evidence the LFP program may serve as a complement to the PRF program, as ranchers who received payments from the LFP program were more likely to enroll in the PRF program (Carlson 2017). Individuals commonly respond strongly to losses, as the subjective weight of potential losses is greater than potential gains (Kahneman and

Tversky 1979). For example, a severe drought in the previous year will likely make the individual more likely to purchase protection in the current year. Therefore, payments from the LFP may increase the subjective probability of downside weather outcomes.

In this model, the choice variables are quantity of rancher inputs (X_{it}), coverage level selection (G_{it}), acres insured (a_{it}), percent of acreage allocated to an interval selection (H_{it}), and productivity factor (p_{it}). All other variables are considered exogenous parameters. The main variable of interest is the impact of the county base value (V_{it}) on acres enrolled and coverage level selection, which is introduced in the premium and indemnity payments. To obtain predictions of how changes to exogenous variables impact ranchers' endogenous choice variable decisions, we can use comparative statics. In particular, we take the first-order conditions (FOC) of the rancher's expected profit equation with respect to the CBV to determine the associate directional change in rancher's coverage and acreage choices in the PRF program (Equation 4.2).

$$\frac{\partial \pi}{\partial V_{it}} = \left[\frac{\partial (\sum_{s=1}^{S=n} I_{it}[R_t^b, R_t, V_{it}, G_{it}, a_{it}, p_{it}, H_{it}])}{\partial V_{it}} - \frac{\partial \lambda (\sum_{s=1}^{S=n} \theta_{it}[L_{it}, PR_{it}])}{\partial V_{it}} + \frac{\partial \lambda (M_{it}(\pi_{it-1}, B_{it}(E_{it})))}{\partial V_{it}} \right] = 0 \quad (4.2)$$

A change to the CBV impacts both premium costs and indemnity revenue payments for the rancher. A higher CBV will lead to a higher premium, holding all other variables constant, but may also lead to a higher indemnity payment conditional on rainfall deviations from the historical average. We hypothesize a higher premium payment will cause a rancher to reduce their willingness to insure or to lower the cost by reducing the coverage level or productivity factor, *ceteris paribus*. Conversely, a reduced premium

payment will allow a rancher to insure additional acreage for the same value or at a higher coverage level or productivity factor to maximize profit.

First-order conditions present an ambiguous hypothesis for rancher profits. The expected sign is dependent on the difference between the indemnity and premium payments. Therefore, we anticipate the ranchers' decisions for acreage enrollment and coverage level selection are contingent on the capital constraint, as we assume previous year's profits or the available borrowing amount impacts how a rancher will insure under the PRF program.¹¹

For this study, we assume the theory of rational expectations holds, as future expectations influence individuals' decisions (Muth 1961). For a profit-maximizing rancher, we assume historical rainfall conditions and the previous year's indemnity, in relation to the premium payment, influence future expectations regarding the PRF insurance program. An indemnity is triggered by deviations from the average rainfall level from the historical rainfall index. If the historical rainfall index reveals a higher variability or a higher probability of receiving low amounts of rainfall, the rancher may

¹¹ It should be noted a rancher will only participate in the PRF program if the following conditions are met: 1) the expected indemnity is higher than the expected premium ($E[I_{it} - \theta_{it}] > 0$) and 2) available liquidity is large enough to cover total premium costs ($M_{it}(\pi_{it-1}, B_{it}(E_{it})) > \theta_{it}[V_{it}, L_{it}, a_{it}, s_{cit}, p_{it}, F_{it}] + \sum_{j=1}^J w_{ijt} X_{ijt} + C_{it}$). However, risk-averse individuals may enroll in the insurance program even if the expected indemnity is less than the premium. For this study, we assume risk neutrality, and we do not take risk aversion into account.

anticipate they are at a higher risk of experiencing losses related to adverse rainfall conditions. Individuals commonly display memory anchoring, the dependence on the available piece of information to make decisions (Kahneman 1992). Therefore, the historical rainfall and the previous year's indemnity payment would likely influence a rancher's decision to purchase insurance protection. To test this hypothesis, we obtain the comparative statics of ranchers' profits with respect to the historical rainfall index (equation 4.3).¹²

$$\frac{\partial \pi}{\partial R_t^b} = \left[\frac{\partial (\sum_{s=1}^S l_{it}[R_t^b, R_t, V_{it}, G_{it}, a_{it}, p_{it}, H_{it}])}{\partial R_t^b} + \frac{\partial \lambda(M_{it}(\pi_{it-1}, B_{it}(E_{it})))}{\partial R_t^b} \right] = 0 \quad (4.3)$$

Despite comparative statics yielding ambiguous results (equations 4.2 & 4.3) for how changes to the CBV and loss ratios impact PRF insurance purchasing decisions, this theoretical model provides helpful insights on ranchers' decision making. Ranchers' decisions when purchasing PRF insurance are constrained by their available liquid capital, as well as the perceived risk of purchasing. Therefore, a rancher will not purchase the insurance if they do not have enough available capital or if they believe they will receive an indemnity greater than the premium paid. This theoretical profit maximization model provides the framework motivating the following empirical analysis. Empirically,

¹² Although not explicitly stated in the theoretical model, we capture the impacts of future expectations on participation and coverage level decisions by including the previous year's average loss ratio for each county.

we seek to identify the direction and magnitudes of the relationship between CBVs with both acreage enrollment and coverage level decisions.

CHAPTER FIVE

DATA ANALYSIS AND DISCUSSION

This thesis uses data from the Risk Management Agency (RMA), National Agricultural Statistics Service (NASS), and Farm Service Agency (FSA) as well as the U.S. Bureau of Economic Analysis (BEA), United States Drought Monitor (USDM), and Chicago Mercantile Exchange (CME). The RMA designs and administers agriculture insurance products and provides data for these products through the publicly available Summary of Business database (SOB).¹³ The SOB is a national dataset with information on all RMA administered insurance products. The SOB reports liability, premium, premium rate, indemnity, subsidy, and insured acres split by county, coverage, and interval selection. The RMA also provides annual county base values (CBV), the established production values of grazing and hay land forage, to estimate changes in buying decisions related to reductions or increases in CBVs. The NASS census is conducted once every five years and by law requires all farms, ranches, and any other agriculture operation to provide all information asked by the census, regardless of size.¹⁴ The census reports on a wide variety of topics, including information on production, economics, and demographics. For this study, the 2017 census provides information on

¹³ <https://www.rma.usda.gov/SummaryOfBusiness>

¹⁴ <https://www.nass.usda.gov/Publications/AgCensus/2017/index.php>

total available acreage for pastureland at the county level. The FSA administers the Livestock Forage Disaster Program (LFP), a disaster assistance program designed to mitigate forage losses due to droughts. Due to the commonalities between the LFP and PRF programs, participation in the LFP program may impact enrollment and coverage level selection within the PRF program. Therefore, we obtain data from the FSA on LFP payments and month eligibility. We control for county farm income, and fall drought conditions in this analysis with data from the BEA and USDM, respectively.¹⁵

Additionally, the CME provides data on national feeder cattle and corn futures prices.

This study narrows the focus to 11 western states due to the region's high enrollment in the PRF program, likely attributed to the semi-arid to arid climate conditions. The 11 states included in the analysis are Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. Despite these states only accounting for 20% of the beef supply, in 2019, they were responsible for over 70% of acreage enrolled in the PRF program with some of the highest total acreage enrolling states being Arizona, Nevada, and New Mexico.¹⁶

While PRF insurance covers both grazing and hay acreage, we examine grazing acreage alone, as grazing acres account for over 99% of insured acreage each year within

¹⁵ BEA data from - <https://apps.bea.gov/iTable/iTable.cfm?reqid=99&step=1#reqid=99&step=1>, USDM data from - <https://droughtmonitor.unl.edu/Data.aspx>.

¹⁶ Estimation obtained from the Summary of Business.

the PRF program. The dataset includes 434 observations aggregated at the county level for years 2016 through 2019 for insured non-irrigated grazing acreage.

RMA Summary of Business Data

The RMA is responsible for developing market-based risk management tools for American agricultural producers to provide stability for those producers and the rural communities where they live. To achieve this, the RMA design agriculture insurance products to be sold and serviced by approved insurance providers (AIP) across the nation. To better assess the effectiveness of each program, the RMA collects data from AIPs to be made public on the SOB. The SOB is a panel data-set dating back to 1989, providing county-level information on premiums collected, premium subsidies, indemnities paid, the liability of current crops covered, and total acreage enrolled for every insurance product administered by the RMA. These data are split by county, coverage level, and interval selection with information on crop insured, irrigation practice, as well as specific certifications of the product.

The SOB report contributes data on the majority of the explanatory variables, as well as the primary dependent variables of interest: proportion of acreage enrolled and coverage level choices. We measure participation as the proportion of acreage enrollment

as total insured acres divided by total available acres for county i in year t as shown in equation 5.1.¹⁷

$$Participation_{it} = \frac{Insured\ Acres_{it}}{Total\ Available\ Acres_{it}} \quad (5.1)$$

As shown in figure 5.1, we find some counties report insured acres that exceed total available acres. Nevada, Utah, and Arizona is where most over-enrollment has occurred. However, this pattern appears to be increasing over the years in more states counties. We predict an underreported available pasture acreage estimate may cause this over-enrollment estimate. To control for overreported enrollment, we remove outlier observations reporting participation over 200% (19 observations are removed by this method). Table 5.1 shows further summary statistics for county-level participation, aggregated at the state level. When aggregated at the state level, over-enrollment is not as prevalent, but not all counties participate in the PRF program as enrollment shows to be stronger in certain regions of each state (shown in figure 5.2).

¹⁷ Pastureland available acres is contributed from the 2017 NASS Census at the county level.

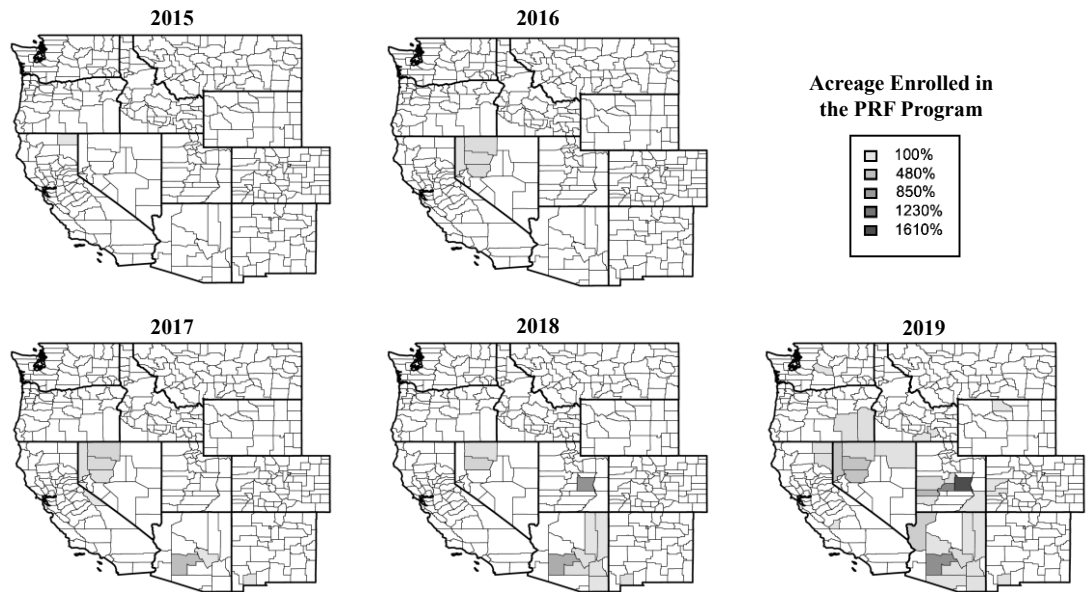


Figure 5.1 Acres Enrolled in the PRF Program Exceeding the Reported Available Pasture Acres in the Western United States

SOURCE: USDA-RMA Summary of Business

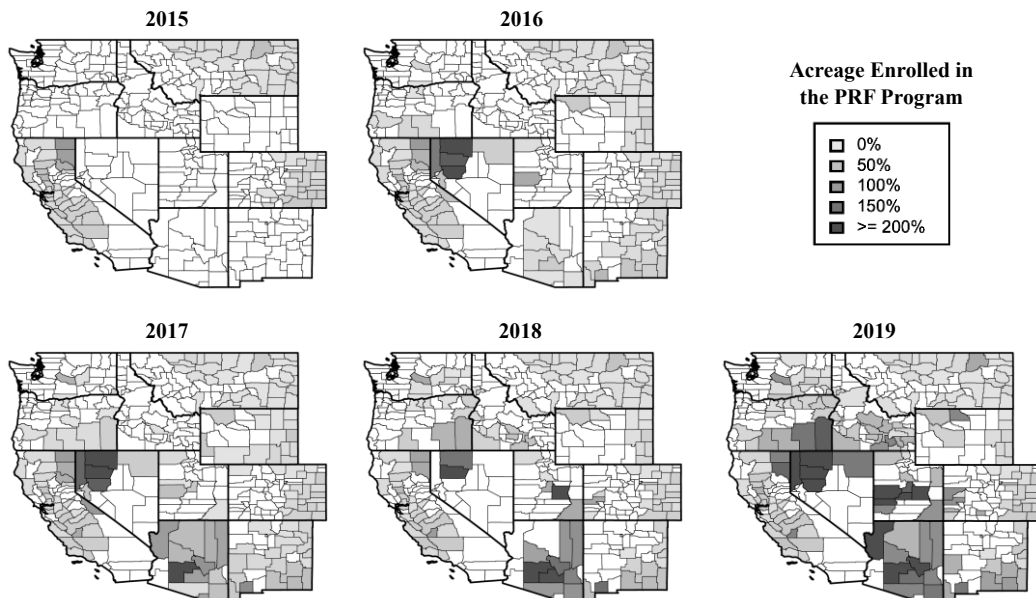


Figure 5.2 Proportion of Available Acres Enrolled in the PRF Program in the Western United States

SOURCE: USDA-RMA Summary of Business

Table 5.1: Average County-Level Participation (Proportion of Available Acres Enrolled) Summary Statistics by State – Years 2016-2019

	N	Max	Min	Mean	SD
Arizona	39	10.415	0.029	1.441	2.036
California	159	1.654	0.012	0.274	0.278
Colorado	119	1.152	0.006	0.179	0.199
Idaho	33	1.235	0.020	0.498	0.288
Montana	156	0.786	0.001	0.078	0.095
Nevada	65	4.787	0.303	2.063	1.400
New Mexico	19	1.533	0.025	0.322	0.318
Oregon	39	1.775	0.014	0.268	0.373
Utah	23	17.629	0.033	2.456	4.505
Washington	28	1.040	0.006	0.201	0.248
Wyoming	47	1.219	0.006	0.154	0.195

SOURCES: Summary of Business and NASS Census.

Coverage level decisions, shown in equation 5.2, are represented by a weighted average coverage level computed by taking the summation of proportion of acres enrolled for county i , coverage level c , and year t multiplied by the corresponding coverage level.

$$CvgLvl_{ict} = \sum_{c=0.70}^{0.90} \left(\left(\frac{Acres\ Enrolled_{ict}}{\sum_{c=0.70}^{0.90} Acres\ Enrolled_{ict}} \right) * Coverage\ Level_i \right) \quad (5.2)$$

Purchasers can choose a coverage level between 70% and 90%. Therefore, the average coverage level for each county is in the mid-to-high 80s, as displayed in table 5.2.

Table 5.2: State Weighted Coverage Level Summary Statistics – Years 2016-2019

	N	Max	Min	Mean	Median	SD
Arizona	101	0.895	0.767	0.839	0.841	0.038
California	292	0.889	0.792	0.841	0.847	0.018
Colorado	208	0.900	0.747	0.858	0.862	0.032
Idaho	140	0.900	0.821	0.866	0.863	0.021
Montana	152	0.900	0.758	0.843	0.847	0.037
New Mexico	200	0.873	0.750	0.814	0.812	0.034
Nevada	91	0.875	0.848	0.860	0.860	0.014
Oregon	118	0.900	0.797	0.858	0.855	0.019
Utah	149	0.900	0.792	0.861	0.860	0.024
Washington	56	0.900	0.806	0.882	0.894	0.021
Wyoming	66	0.900	0.766	0.865	0.870	0.029

SOURCE: RMA Summary of Business

NOTES: Estimates are the mean across counties within each state.

Figure 5.3 displays the total acres enrolled in the PRF program for all western states aggregated by each coverage level. As shown, the coverage level selections that are most frequently enrolled in are 85% and 90%, and the least standard selections are 70% and 80%.

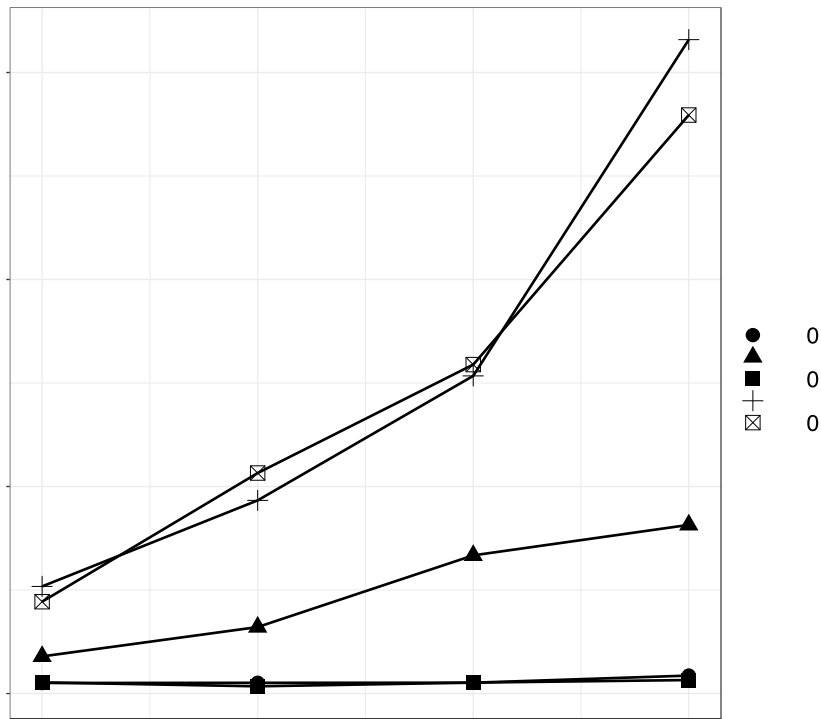


Figure 5.3 Total Acres Enrolled in the Western States in the PRF (Aggregated by Coverage Level)

SOURCE: USDA-RMA Summary of Business

The RMA SOB contributes data on premiums, subsidies, and indemnities that we use to calculate a county's average loss ratio. Interpretations for a loss ratio is the dollar indemnified for every dollar paid in premium. The loss ratio used for this study is a one-year lagged variable included to estimate how previous year's indemnity, relative to the premium payment, impacts livestock producers decisions to purchase PRF insurance in

the current year.¹⁸ To calculate the loss ratio (equation 5.3), the indemnity is divided by the producer-paid (post-subsidy) premium for county i and year t .

$$Loss\ Ratio_{it-1} = Indemnity_{it-1} / (Premium_{it-1} - Subsidy_{it-1}) \quad (5.3)$$

Additionally, the SOB provides the average premium rate for each county.¹⁹

Premium rates are representative of the cost of insurance per liability to cover claims payments, expenses, and commissions to agents. Methods to calculate the PRF program's premium rates are not publicly available. However, we know calculations take into consideration past losses to reliably predict future losses in order to estimate actuarial fair premium rates. Therefore, we would expect higher premium rates charged to higher risk counties and vice versa. A point to be noted is that insurance experience data are only available for counties that participate in the PRF insurance program. Therefore our premium rates may understate actual rates faced by the entire insurance pool, as we do not observe nonbuyers who may face higher rates (Goodwin, Vandever and Deal 2004).

Frequently observed, producers with different expected returns (loss ratios) have different responses to premium rate changes. Goodwin (1993) explains that not adjusting for differing responses will likely deflate the premiums for producers who typically

¹⁸ Goodwin (1993) and Goodwin, Vandever, and Deal (2004) use a multiple-year averaged loss ratio to control for years of exceptional losses impact on participation in crop insurance. Due to the limited size of our time-series, we do not implement an averaged loss ratio.

¹⁹ We average premium rates between both hay and pasture acreage insured. Therefore, overestimated estimates may be present. However, given the substantially lower rates of hay acreage insured in the program, we still believe this is an accurate estimation.

receive higher indemnities relative to premiums and will inflate premiums for those who generally receive lower indemnities. To control for this effect, we calculate an interaction between the premium rate and the expected loss ratio.

The RMA also provides data on the PRF CBV used to measure the effect changes to CBVs have on producer's participation and coverage level selection. As mentioned in the background section, the RMA has made considerable alterations to CBVs in the last four years. In 2016, rainfall index insurance was made available to all western states. However, CBV estimates switched to a state-level evaluation along with incorporating additional data to assess land productivity better. In 2018, the RMA switched to assessing values at the agricultural district level and incorporated additional data to account for different growing conditions and actual land rental rates. For many counties, this resulted in lower CBVs than what was initially estimated, as shown in figure 5.4.

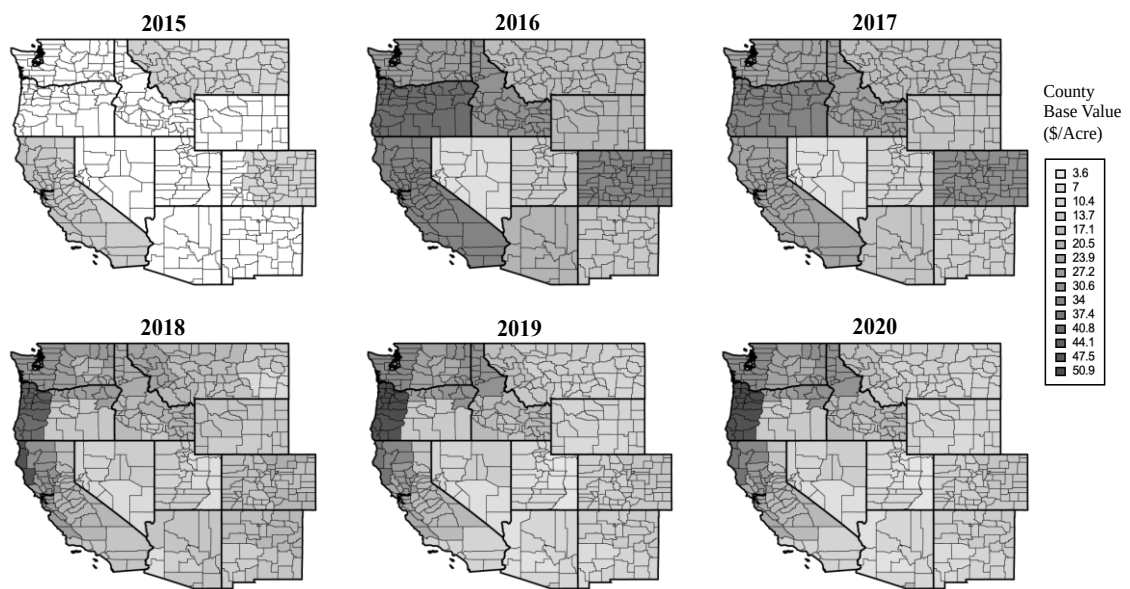


Figure 5.4 County Base Value Changes from Years 2015-2020
SOURCE: USDA-RMA

Total western United States acres insured in the PRF have drastically increased in the last four years, as depicted in figure 5.5. We partially attribute this increase in enrollment due to the abandonment of the vegetation index in 2016, used to trigger indemnities for most western states aside from California, Montana, and parts of Colorado. While a majority of western states offered the vegetation index, the index did not gain much popularity. One theory attributes this lack in popularity to a perception of the vegetation index, having a weak correlation with actual losses. By including previous years, when the RI-PRF was unavailable to all western states, results would likely be biased as the expansion of the program caused a substantial increase in enrollment. To isolate any effects on participation by our main variables of interest, we only include years' 2016-2019.

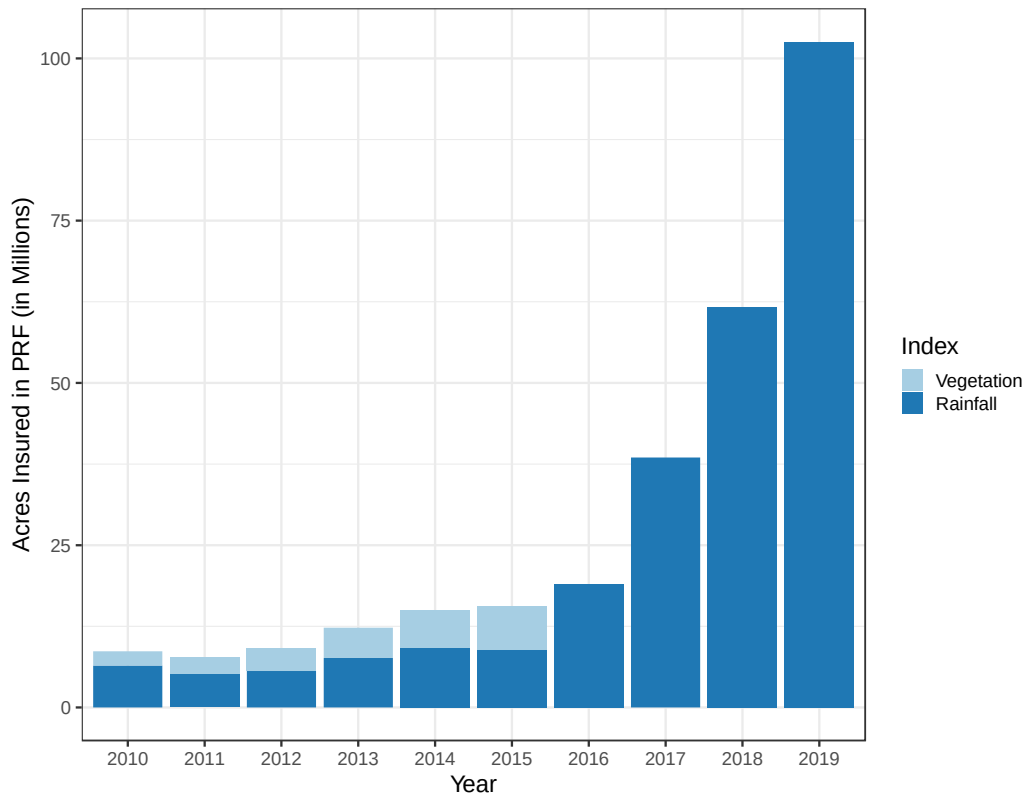


Figure 5.5 Total Acres Enrolled in the PRF Within Western States from 2010-2019
(Under Both the Vegetation and Rainfall Index)

SOURCE: USDA-RMA Summary of Business

Livestock Forage Disaster Forage Program Data

The 2008 Farm Bill, introduced the LFP program as one of the "Supplemental Agriculture Disaster Assistance" programs. This program was expanded and made permanent in the 2014 Farm Bill. The program compensates eligible livestock producers who have experienced grazing losses due to drought conditions. In contrast to the PRF

program, no prior enrollment is necessary for livestock producers.²⁰ Instead, a producer may apply for compensation within 30 days of the end of the calendar year in which the loss occurred. Another divergence from the PRF program is the LFP's use of the drought monitor index (USDM) rather than a rainfall index. Use of the drought monitor could lead to more accurate indemnities as it accounts for more than just precipitation (i.e., temperature, wind speed).

The LFP bases eligibility and degree of payment off the USDM. The USDM is a publicly available map releasing data on the drought conditions in the U.S. every week. The USDM combines data from the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln, the National Oceanic and Atmospheric Administration (NOAA), and the USDA. Five categories are used to categorize droughts. D0 is the lowest category, described as being abnormally dry, followed by D1 (moderate drought) and D2 (severe drought). Each of these categorizations expects some pasture losses. The highest drought categorizations are D3 (extreme drought) and D4 (exceptional drought), where pasture losses and water shortages are almost always guaranteed: tables 5.3 and 5.4 present further explanation of the USDM drought categorization.

²⁰ Before 2014, the LFP did require producers to be enrolled in either the VI-PRF program or the Non-Insured Assistance Program (NAP) to be eligible for LFP payments. Additionally, the LFP required a buy-in requirement to obtain payments (USDA-FSA 2008).

Table 5.3 USDM Drought Categorization Description and Attribute Ranges

Category	Description	Ranges				
		Palmer Drought Severity Index (PDSI)	CPC Soil Moisture Model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	-1.0 to -1.9	21 to 30	21 to 30	-0.5 to -0.7	21 to 30
D1	Moderate Drought	-2.0 to -2.9	11 to 20	11 to 20	-0.8 to -1.2	11 to 20
D2	Severe Drought	-3.0 to -3.9	6 to 10	6 to 10	-1.3 to -1.5	6 to 10
D3	Extreme Drought	-4.0 to -4.9	3 to 5	3 to 5	-1.6 to -1.9	3 to 5
D4	Exceptional Drought	-5.0 or less	0 to 2	0 to 2	-2.0 or less	0 to 2

SOURCE: U.S. drought monitor index

Table 5.4 USDM Drought Categorization Description and Possible Impacts

Category	Description	Possible Impacts
D0	Abnormally Dry	Going into drought: • Short-term dryness slowing planting, growth of crops or pastures Coming out of drought: • Some lingering water deficits • Pastures or crops not fully recovered
D1	Moderate Drought	• Some damage to crops, pastures • Streams, reservoirs, or wells low, some water shortages developing or imminent • Voluntary water-use restrictions requested
D2	Severe Drought	• Crop or pasture losses likely • Water shortages common • Water restrictions imposed
D3	Extreme Drought	• Major crop/pasture losses • Widespread water shortages or restrictions
D4	Exceptional Drought	• Exceptional and widespread crop/pasture losses • Shortages of water in reservoirs, streams, and wells creating water emergencies

SOURCE:U.S. drought monitor index

To be eligible for LFP payments, a grazing livestock producer's county must be in at least a D2 rating for eight consecutive weeks during the normal grazing period (eligible

for one month of payment). Counties in more severe droughts can be eligible for payment with a reduced time requirement. A D3 rating at any time is eligible for three months' pay or four months' pay if the rating lasts for four consecutive weeks. A D4 rating at any time is eligible for four months' pay or five months if the category lasts four weeks (does not payments from 2015 to 2019. Figure 5.6 displays the western states month eligible for payments from 2015 to 2019. Although, no distinct pattern seems to occur, most counties in the west were not eligible for LFP payments with the exception of 2015.

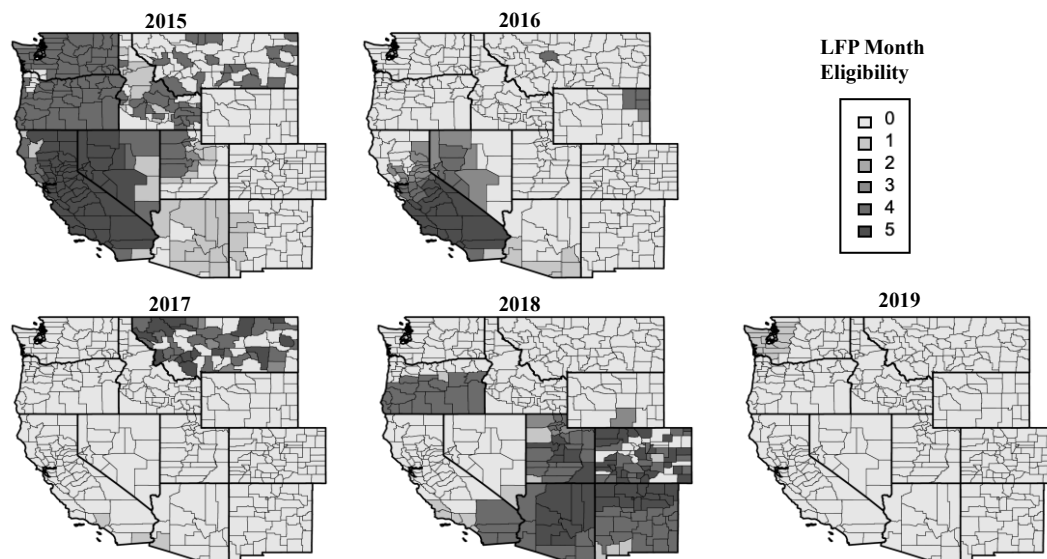


Figure 5.6 Months Eligible for LFP Payments in the Western United States, Years 2015-2019

SOURCE: USDA-FSA

An LFP payment is dependent on how long a county is in a drought during the grazing season, the severity of the drought, and the livestock producer's size of their operation. LFP monthly payments are equal to 60% of the lesser of either monthly feed cost for all covered livestock, or a calculation of the standard carrying capacity of the

eligible grazing land.²¹ Table 4.5 shows the summary statistics for the LFP payment data used in this study. These data only include occurrences when a county received a payment; it does not include counties that applied and received no payment from years 2011 to 2019, with California having the most frequencies and Washington having the least.

Table 5.5: State (Averaged Across Counties) LFP Payment Summary Statistics (\$/County) – Years 2011-2019

	N	Max	Min	Mean	SD
Arizona	101	5,220,102	1,353	724,396	831,071
California	292	5,237,115	620	844,875	918,221
Colorado	208	6,205,716	69	1,109,636	1,279,077
Idaho	140	4,914,005	542	332,586	653,160
Montana	152	7,965,355	346	1,203,749	1,609,221
New Mexico	200	6,877,915	1,407	1,112,661	1,172,248
Nevada	91	4,109,253	1,265	760,776	1,064,388
Oregon	118	8,817,267	716	1,210,745	1,928,578
Utah	149	3,637,804	454	707,591	768,063
Washington	56	2,241,647	571	270,204	389,717
Wyoming	66	6,929,713	2,813	2,596,242	2,005,516

SOURCE: USDA-Farm Service Agency

It is unclear whether and to what extent the LFP program impacts the PRF program as both mitigate related risks, but function quite differently in terms of

²¹ Exceptions to the payment rate include if ranchers disposed of livestock due to drought conditions and if livestock producers were using federal rangeland. In the circumstance of disposed of livestock, the payment rate is 80 percent of monthly feed costs. For federal rangeland, payments begin the day livestock producers are prohibited from grazing and end on the last day of the federal contract or at the end of a 180 calendar-day period. Payments for federal rangeland circumstances are 50% of monthly feed costs.

enrollment and indemnity triggers. To determine if any relationship exists between enrollment and coverage level choices in the PRF program and LFP program, we include data on total LFP payments received within a county and LFP month eligibility.

Futures Price Data

The Chicago Mercantile Exchange (CME) is a global marketplace that is an extensive options and futures contract world exchange. Commodities traded include, energy, equity, bonds/interest rates, and agriculture products. Included in agriculture contracts are feeder cattle and corn futures prices, which are both used in this study. Feeder cattle and corn futures prices are reported as the average future contract price in September as reported in the previous year during November. We chose this month estimate as we predict it is the most critical to producers enrolling in the PRF insurance program, as November is the last month to enroll.

We introduce both corn and feeder cattle futures prices into the model to estimate how ranchers' future expectations of the market influence their participation and coverage level selections in the PRF insurance program. Ranchers' future expectations for output prices and input costs can have a strong influence on their decisions when optimizing profits. Corn, which accounts for 91% of the grains used for cattle feed, typically impacts a cow-calf rancher indirectly (USDA-ERS 2016). Cow-calf producers generally use a pasture-based feeding regimen for their cattle. Therefore, increased corn prices will not impact a rancher's feeding inputs, but it will affect a rancher's output prices. Cow-calf operations produce cattle to be sold to feedlots, where they will be put on grain-based diets to reach an optimal condition for harvest. Higher corn prices will

increase feedlots input costs and place downward pressure on demand for feeder cattle response, thus lowering cow-calf producers' revenue.

Other Explanatory Variable-Data

In addition to the SOB, LFP, and futures data, we control for farm earned income and fall drought conditions. The BEA contributes data on farm earned income at the county level. To estimate county farm income we calculate a five year average. Farm earned income is a proxy for the financial flexibility within a farm operation. Higher cash flow flexibility may lead to lower cash flow constraints, and we hypothesize it would allow purchasers to enroll additional acres or at higher coverage levels (Boyd 2019).

The last month to enroll in the PRF program is November. During that time, we hypothesize livestock producers take into consideration current weather conditions when enrolling. For example, a dry fall may lead a rancher to anticipate a dry spring or vice versa. Therefore, we create a binary variable to control for a drought occurring in November of the previous year. Using the USDM data, the fall drought variable takes on the value of 1 if a county i has a drought rating of D2 or above anytime during November in year $t - 1$.

$$Fall\ Drought_{it-1} = \begin{cases} 0 & USDM\ Rating < D2\ for\ any\ week\ in\ November \\ 1 & USDM\ Rating \geq D2\ for\ any\ week\ in\ November \end{cases} \quad (5.4)$$

A summary statistic of these variables and other explanatory variables, along with their definitions, are included in table 5.6 and 5.7.

Table 5.6: Summary of Variable Definitions

Variable Name	Units	Definition	Source
County Base Value	\$ per acre	Valuation of a county's pasture acreage to be indemnified in the event of below-average rainfall.	USDA-RMA
Expected Loss Ratio	Dollars of indemnities received per dollar paid in premiums	Previous year's average loss ratio within the county, coverage level, and interval selection. Loss ratio = Indemnity/Premium payments, where premium payments are the sum of farmer paid premiums and subsidies.	USDA-RMA
Premium Rate	\$ per liability unit	The Price of insurance for each unit of liability, determined by predictions of future losses.	USDA-RMA
Log(Income per Farm)	Percent increase	Five year average of total income earned from farming operations reported at the county level.	BEA
Lag(LFP Months)	Months eligible for LFP payments	Areas that receive severe drought conditions, characterized by the drought monitor index, may be eligible to collect LFP payments. LFP payments can be eligible for up to 5 months.	USDA-FSA
Lag(LFP Payments)	\$10,000	Areas eligible for LFP payments, determined by the drought monitor index, may receive payments to offset grazing losses. This variable shows the previous year's net revenue received from LFP payments in each county.	USDA-FSA
Lag(Fall Drought)	0 = No drought 1 = Drought	Using the drought monitor index, counties with a category D2 and above drought during November receive the binary value of 1. All counties that do not have a drought category D2 or above receive a value of 0.	USDM
Corn Futures Price	\$ per Bushel	The average future contract price due in September reported during the previous year's month of November.	CME
Feeder Cattle Futures Price	\$ per lb.	The average future contract price due in September reported during the previous year's month of November.	CME

Table 5.7: Summary Statistics of County-Level Data

Statistic	N	Max	Mean	Min	Median	SD
County Base Value	434	49.10	18.69	3.60	16.00	8.76
Loss Ratio	434	5.19	1.77	0.00	1.54	1.07
Premium Rate	434	5.19	1.77	0.00	0.19	1.07
Log(Farm income)	434	7.76	6.79	1.10	7.02	0.94
LFP Months	434	5.00	1.26	0.00	0.00	2.02
LFP Payments	434	618.17	57.03	0.00	0.00	100.07
Fall Drought	434	1.00	0.28	0.00	0.00	0.45
Feeder Cattle Futures Price	434	167.00	144.50	117.20	149.20	17.95
Corn Futures Price	434	393.70	383.90	375.00	387.80	7.45

SOURCES: The Risk Management Agency (RMA) records county indemnities, premiums, and subsidies used to calculate the loss ratios, as well, yearly county base values. The Bureau of Economic Analysis (BEA) calculates income earned from farming operations at the county-level. The Farm Service Agency (FSA) provides data on LFP. Drought monitor index data determine if fall drought conditions impact purchasing choices. Chicago Mercantile Exchange (CME) contributes feeder cattle and corn futures prices.

CHAPTER SIX

EMPIRICAL METHODOLOGY

In this research, we empirically evaluate the determinants of purchasing decisions in the PRF insurance program. Specifically, we evaluate the relationship between changes in county base values (CBVs), effectively impacting program premiums and potential indemnities, with livestock producers' decisions to participate in the PRF insurance program and select a particular coverage level. Equation 6.1 displays our estimated linear regression equation for PRF participation (measured as a percentage). We include explanatory variables CBVs, in dollars per acre (CBV_{it}), the lagged rancher paid loss ratio (LR_{it-1}), average premium rate (PR_{it}), the interaction between average premium rate and expected loss ratio ($PR_{cit} * LR_{it-1}$), income earned from farming operations in the prior year (FI_{it-1}) in log form, the amount of LFP payments received in the previous year for a county in \$10,000 (LP_{it-1}), total months eligible in the previous year for LFP payments (LM_{it-1}), and a binary variable that is equal to one when a fall drought is rated level D2 or higher in November (FD_{it-1}) and zero otherwise. Additionally, we control for expected feeder cattle prices (FC_t) and expected corn prices (CP_t) using the futures price due in September, as reported in November of the previous year, for each. Our dependent variable is participation, as measured by the proportion of acres enrolled in the PRF insurance program ($Part_{it}$) for county i in year t . To measure

coverage level decisions, equation 6.2 uses the same explanatory variables as equation 6.1, but regresses on a weighted average coverage level ($CovL_{it}$) for county i in year t .

$$Part_{it} = \beta_0 + \beta_1 CBV_{it} + \beta_2 LR_{it-1} + \beta_3 PR_{it} + \beta_4 (PR_{it} * LR_{it-1}) + \beta_5 FI_{it-1} + \beta_6 LFP_{it-1} + \beta_7 LM_{it-1} + \beta_8 FD_{it-1} + \beta_9 FC_t + \beta_{10} CP_t + \varepsilon_{it} \quad (6.1)$$

$$CovL_{it} = \beta_{11} + \beta_{12} CBV_{it} + \beta_{13} LR_{it-1} + \beta_{14} PR_{it} + \beta_{15} (PR_{it} * LR_{it-1}) + \beta_{16} FI_{it-1} + \beta_{17} LFP_{it-1} + \beta_{18} LM_{it-1} + \beta_{19} FD_{it-1} + \beta_{20} FC_t + \beta_{21} CP_t + \varepsilon_{it} \quad (6.2)$$

The final term ε_{it} represents the unobservable characteristics not being controlled for that are influencing a livestock producer's decision to enroll additional acres or choose a specific coverage level. Other variables considered but removed in these models include satellite density (SD) accounting for the total number of precipitation satellites within a 50-mile radius of a county, and a county average drought occurrence for each drought rating (i.e., D1, D2, D3, D4).

Fixed Effects Model

A potential concern when using a panel data set is unobserved heterogeneity bias, which occurs when omitting a time-constant variable. A fixed-effect (α_i) and random

effect (v_{it}) make up the OLS equations error term.²² For OLS to produce unbiased and consistent coefficient estimates, the unobserved fixed-effect (α_i) has to be uncorrelated with all other regressors (Wooldridge 2013). For this study, we suspect a correlation is present between the fixed-effect and other regressors in our equation. To control for this, we implement a least-squares fixed-effect dummy (LSDV) model. The fixed-effect model applied controls for any potential unobservable agricultural district-level characteristics (e.g., vegetation, insurance agent density, extension outreach) that may impact either participation decisions or coverage level selection. We separately consider state, agricultural district, and county-level fixed-effects for this model. Participation for a county is determined by acreage and differs quite significantly across states, as displayed in figure 6.1. We expect that state-level fixed-effects would explain a large amount of variation if the other explanatory variables are not already accounting for it.

²² The error term is represented by the following equation: $\varepsilon_{it} = \alpha_i + v_{it}$. The fixed effect term (α_i) represents all unobserved, time constant factors affecting the dependent variable. The random effect term (v_{it}) represents all unobserved, time-varying factors affecting the dependent variable (often referred to as the idiosyncratic error; Wooldridge 2013).

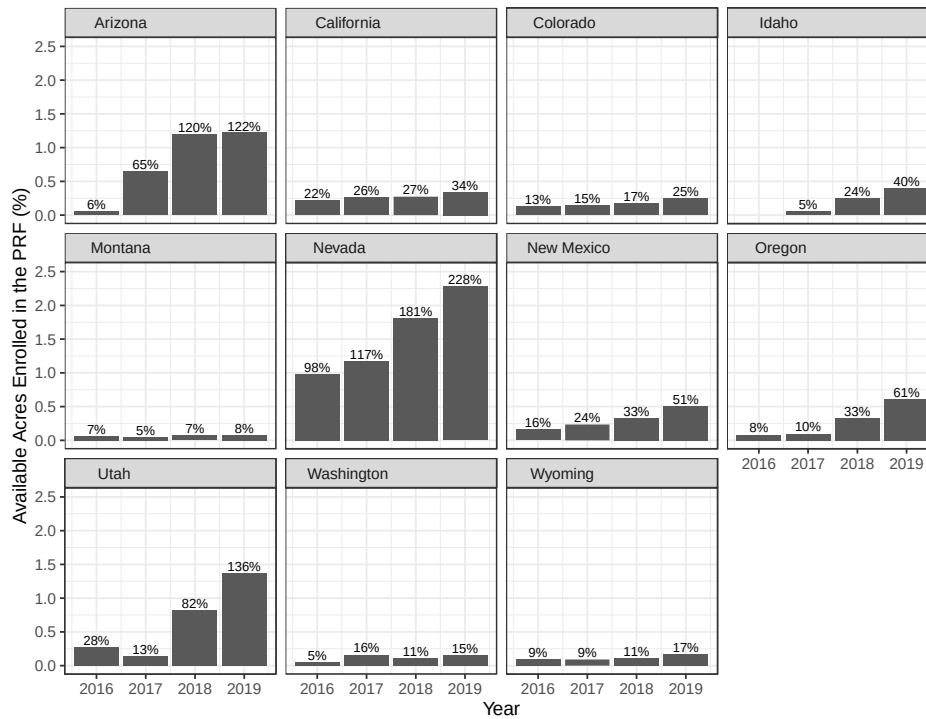


Figure 6.1 Proportion of State Available Pastureland Enrolled in the PRF Program (Summed Across Counties)

SOURCE: RMA-Summary of Business

NOTES: Some states display that acreage enrolled exceeds the available acres. This over-enrollment is likely due to an underreported available pasture acreage.

We consider agricultural district-level fixed effects, as the RMA switched their CBV evaluation from the county level to the district level in 2018. Additionally, we considered county-level fixed effects for this study, but due to the time series sample size, the inclusion of these fixed effects leaves at most four observations per county. Therefore, we expect the inclusion of county fixed effects would not have enough power to obtain accurate estimates. In order to obtain the most precise estimates possible, we use agricultural district-level fixed effects. The variation used in this study to obtain parameter estimates comes from across agricultural districts over time. Agricultural

district-level fixed effects are represented by α_i for agricultural district $i = 1, \dots, d-1$ with d representing the final agricultural district fixed effect in equations 6.4 and 6.5.

$$Part_{it} = \beta_0 + \beta_1 CBV_{it} + \beta_2 LR_{it-1} + \beta_3 PR_{it} + \beta_4 (PR_{it} * LR_{it-1}) + \beta_5 FI_{it-1} + \beta_6 LFP_{it-1} + \beta_7 LM_{it-1} + \beta_8 FD_{it-1} + \beta_9 FC_t + \beta_{10} CP_t + \alpha_i + v_{it} \quad (6.4)$$

$$CovL_{it} = \beta_{11} + \beta_{12} CBV_{it} + \beta_{13} LR_{it-1} + \beta_{14} PR_{it} + \beta_{15} (PR_{it} * LR_{it-1}) + \beta_{16} FI_{it-1} + \beta_{17} LFP_{it-1} + \beta_{18} LM_{it-1} + \beta_{19} FD_{it-1} + \beta_{20} FC_t + \beta_{21} CP_t + \alpha_i + v_{it} \quad (6.5)$$

Seemingly Unrelated Regression Equation Model

A potential concern when running both regression equations (6.4 and 6.5) separately is the error terms in both models may be related. It is likely that unobservable factors that influence a ranchers decision to participate in the PRF program also influence their coverage level choice. Therefore, we run a seemingly unrelated regression equation (SURE) model to test whether the two regressions error terms are related. If the error terms are correlated, then the SURE model will provide the more efficient estimates compared to our LSDV estimates (Zellner 1962). The SURE model uses a feasible generalized least squares (FGLS) two-step method to compute estimates. The first step is to estimate each equation using the OLS method. The residuals are taken from the first step regressions and used to estimate the elements of the variance matrix. In the second step, we run a generalized least squares regression using the variance matrix to obtain consistent and efficient estimates (Greene 2003).

Estimates for the SURE model will be the same as our LSDV estimates if both equations contain the same regressors. Therefore, we estimate the coverage level regression (equation 6.7) by using premium rate, CBV, corn futures price, and LFP month eligibility from the previous years as regressors. Additionally, we estimate participation choice by regressing CBV, previous year loss ratio, premium rate, premium rate/loss ratio interaction, and farm earned income (equation 6.6).

$$Part_{it} = \beta_0 + \beta_1 CBV_{it} + \beta_2 LR_{it-1} + \beta_3 PR_{it} + \beta_4 (PR_{it} * LR_{it-1}) + \beta_5 FI_{it-1} + \alpha_i + v_{it} \quad (6.6)$$

$$CovL_{it} = \beta_6 + \beta_7 PR_{it} + \beta_8 CBV_{it} + \beta_9 Corn_t + \beta_{10} LFPMonth_{it-1} + \alpha_i + v_{it} \quad (6.7)$$

Models Excluding Loss Ratios

For this analysis, we use a one-year lagged loss ratio to determine how the previous year's indemnity in relation to the premium impacts producers' decisions in the current year. Due to the rainfall-index program not being offered before 2016 for all western states except for California, Montana, and parts of Colorado, most states do not have loss ratios for 2015. This exclusion of states limits our sample size and additionally could bias our estimates if we only include three states for the first year analyzed. For this reason, we provide models that exclude the lagged loss ratio from the analysis to

determine how observations from counties that did not have the opportunity to enroll before 2016 impact our analysis.

We considered adding zeros in place of missing loss ratios. However, this proved problematic as there are already meaningful zeros included in the loss ratios. A reported zero loss ratio could occur for two different reasons: 1) No person decided to enroll in the program for that year and county, or 2) there was no indemnity in that county. The inclusion of zeros for counties unable to enroll in the RI-PRF program in previous years would add a third reason for why a zero could occur, consequently creating more noise in our estimates. Therefore, to obtain the most precise results, we chose to analyze results both with and without the lagged loss ratios.

Weighted Coverage Level

To measure producers' coverage level choices, we obtain a weighted average coverage level for each county within our dataset. Other literature applies a discrete choice model to determine individuals' insurance choices (Sherrick et al. 2004; Du et al. 2016; Boyd 2019). Individual-level data are currently unavailable from the RMA. Therefore, a discrete choice model could not be employed as individual policy data are not available. Thus, we take a weighted average coverage level for each county in each year to determine changes in coverage level decisions over time.

Explanatory Variables

Loss Ratios

For this study, we calculate a one-year lagged loss ratio to represent the recent loss experience for each county. Effects from an increase in a subsidized recent loss ratio can modify expectations in two ways: through a risk mitigation effect and an income effect. Through the risk mitigation effect, a higher loss ratio may be indicative of the rainfall index having a stronger correlation with actual production losses, thus lowering the perceived basis risk. Purchasers commonly perceive index insurance products as a gamble; hence a lower basis risk will lower the perceived risk of enrolling in the program (Carter et al. 2015). The previous year's loss ratio represents the dollar indemnified for every \$1 paid in subsidized premiums; therefore, a higher possibility of increasing one's income will likely incentivize a producer to insure (Hasenoehrl 2014; Babcock 2015). In the last four years, the producer paid loss ratio has been relatively high for the PRF program within western states. Table 6.1 displays the mean, median, and standard deviation for the loss ratios averaged across states counties. All states average a loss ratio above 1.0, with the highest being 2.667 (Arizona) and the lowest 1.392 (Montana). In addition to Montana having the lowest average loss ratio, it also has one of the highest standard deviations (California with the highest standard deviation at 1.407), indicating a more variable expected loss ratio from year to year. We would expect a high average loss ratio combined with a low variation would provide strong incentives for producers to increase their enrollment.

Table 6.1: State Loss Ratio (Averaged Across Counties)

State	Mean	Median	Standard Deviation	Total State Mean
Arizona	2.667	2.492	1.168	2.230
California	2.140	1.929	1.407	2.258
Colorado	1.399	1.269	0.921	1.776
Idaho	2.503	2.768	0.919	2.298
Montana	1.392	1.084	1.309	1.827
Nevada	1.884	1.999	0.661	2.088
New Mexico	1.788	1.786	0.670	1.819
Oregon	1.859	1.612	0.667	2.509
Utah	2.362	2.805	1.153	2.245
Washington	2.105	2.216	0.516	3.064
Wyoming	1.457	1.438	1.043	1.671
Total	1.769	1.651	1.183	2.162

SOURCE: Summary of Business provides information on premiums, subsidies, and indemnities aggregated at the county level for years 2016-2019.

NOTES: Loss ratios include subsidies; therefore, the premium is the premium paid by the rancher.

Despite the previous loss ratios being relatively high for all counties, future expectations for loss ratios may see reductions due to favorable rainfall conditions in 2019. Figure 6.4 maps the western states' average loss ratio for each county. In 2017, loss ratios showed to be the highest of all years for a majority of counties with many counties averaging loss ratios above two. However, in the following years, this ratio appears to decrease for most counties, which is especially noticeable in 2019. In 2019, most counties did not report an average above one for their loss ratio.

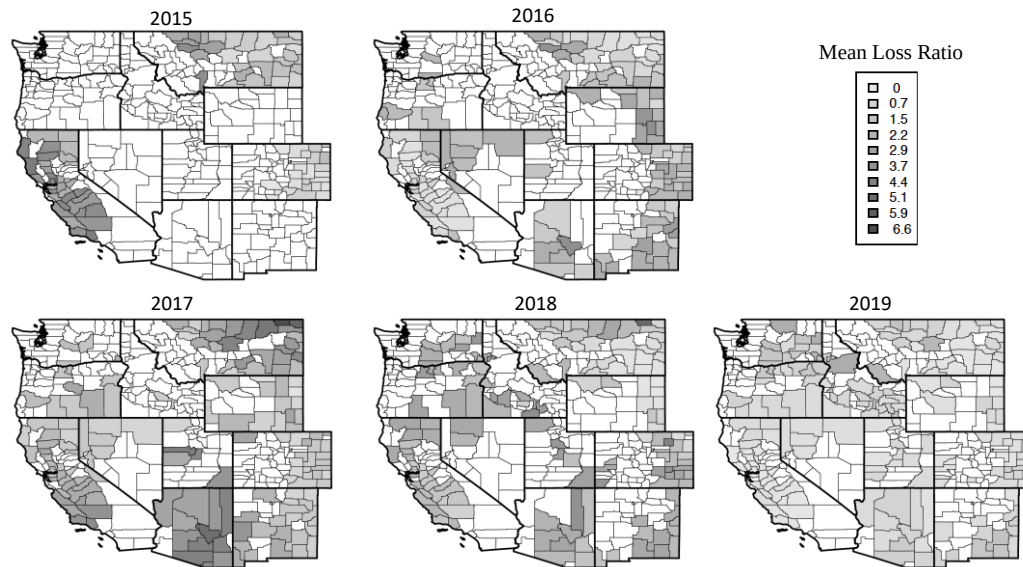


Figure 6.2 Average Loss Ratio for Each County in the Western States from Years 2015-2019

SOURCE: RMA Summary of Business

County Base Values

The CBV is representative of the expected value of the insured land. Changes to the CBV, therefore, impact both premiums paid and potential indemnities received. The potential impact of changes to CBVs on participation and coverage choices can be captured through a risk mitigation effect and/or a budget constraint effect. Reduced CBVs could reduce the PRF program's risk mitigation as the potential indemnity paid is reduced and may not fully cover losses realized compared to previous years. However, an insuring producer can partially account for these reductions since their choice of productivity factor allows to adjust the value placed on their insured land. The second effect regards the budget constraint. If livestock producers disposable income is viewed as fixed, a reduction in CBVs lowers the producer paid premium; therefore, a producer

can insure additional acres or at a higher coverage level for the same, if not less, of a premium payment as before.

Premium Rates

Premium rates are the other component impacting a producer's total premium payment. The calculation for this rate includes the cost to cover potential losses, expense and provide a profit to the insurance provider.²³ A higher premium rate is representative of a higher risk producer, but it also means the producer faces a larger premium payment. Crop insurance literature has found producers to have a relatively price elastic demand, suggesting an increase in price will result in a decrease in quantity demanded (Goodwin 1993). We hypothesize a producers' response to an increase in premium rates will have a negative impact on participation in the PRF insurance program. Ranchers facing a fixed budget constraint will have to either decrease their acreage insured, reduce their coverage level or productivity factor to lower their overall liability in response to an increased premium rate.

Demand responses to price changes is likely to change for different risk producers. Higher risk producers are more likely to participate in the insurance program than low-risk producers (Goodwin 1993). Likewise, higher-risk producers would expect to be indemnified more frequently and at larger amounts. Therefore, we predict higher

²³ Premium payments = Premium Rate*Liability.

risk producers will show less price sensitivity compared to the lower risk producers. To analyze this effect, we include an interaction term between the premium rate and the expected loss ratio. To illustrate this relationship, figure 6.3 shows the presence of the interaction between the expected loss ratio and the premium rate with enrollment in the PRF insurance program.

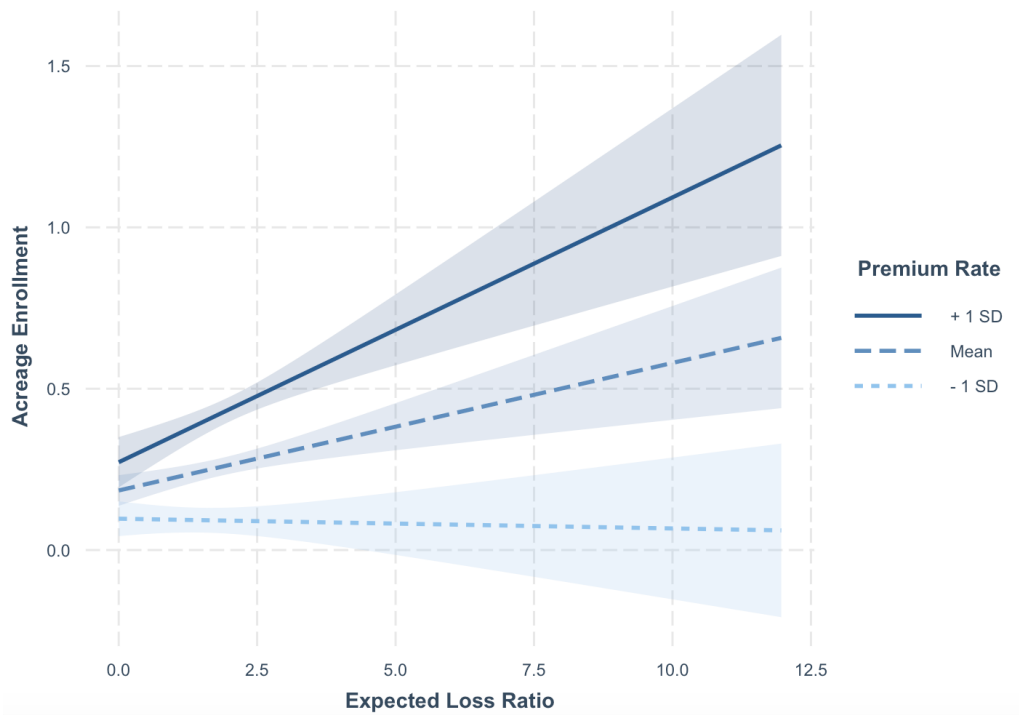


Figure 6.3 Expected Loss Ratio and Premium Rate Relationship Effect on Acreage Enrollment

SOURCE: RMA Summary of Business

Variables Using the U.S. Drought Monitor Index

The PRF program uses a rainfall index to trigger indemnity payments, which only accounts for one temporary factor among a list of long-run factors that impact drought

conditions. Producers who enroll in the PRF program are often attempting to prevent losses from drought conditions; however, for some areas, this may not be the most effective index. For this study, we analyze whether the PRF is impacted by the Livestock Forage Disaster Program (LFP). The LFP uses the U.S. drought monitor index (USDM), which provides a more comprehensive indicator for drought conditions compared to the single peril rainfall index used by the PRF program. Therefore, the LFP may provide coverage with a higher correlation to actual production losses. To test this hypothesis, we provide data on LFP month eligibility as well as the size of payment received within a county for each year.

There are two ways we predict the LFP program could impact participation and coverage decisions in the PRF program. First, the LFP and PRF programs may function as substitutes. The LFP program functions quite differently from the PRF program in which producers do not have to enroll in advance (thus making the LFP the cheaper and potentially lower risk option), and the program takes into account all drought causing aspects, theoretically making it more precise in covering losses related to drought conditions. Due to these differences, producers may view the LFP as an alternative to the PRF. Alternatively, these programs may be complements. Producers can receive risk protection from both programs. A producer may enroll in the PRF program and still qualify to receive payments from the LFP, allowing the producer to receive a payment from both programs if eligible.

Moreover, we predict the LFP's previous years' eligibility may serve as a proxy for the following years' drought conditions. For example, if a producer is eligible for

more months of LFP payments in the previous year, they may be induced to enroll additional acres or at a higher coverage level in the PRF program the current year as they believe they are more likely to experience drought conditions. Alternatively, drought conditions in the previous year may reduce a rancher's income, thus reducing their capability to enroll in the PRF program in the current year.

Along with the LFP serving as a proxy for expectations of future year drought conditions, we also include a fall drought binary variable. This variable assumes the current drought conditions at the time of enrollment may influence producers' purchasing decisions. November is the last month to enroll in the PRF program for the following year. Therefore, we use data from the USDM to create a binary variable for a county with a category D2 drought or higher during any week of November.

Future Prices Variables

Ranchers generate a large portion of their revenue from the sale of their feeder cattle. Feeder cattle price expectations may impact how ranchers manage their cattle (i.e., how long they keep cattle before the auction) and how they allocate their previous year's profit in the current year. A higher futures price for feeder cattle may provide reassurance for market stability and could influence a rancher to make additional investments in the presence of higher anticipated revenue. Therefore, ranchers may increase insurance protection by insuring additional acreage in response to higher expected returns.

Corn is a primary input for feedlot operations, whose main goal is to get cattle to optimal weight and condition for harvest. We include corn futures prices, reported in September of the previous year due in November, in determining how ranchers respond

to the indirect effect of potentially higher market prices. In the occurrence of a more volatile market, we would anticipate ranchers to take additional precautions to safeguard against any potential losses. Therefore, we would expect higher participation in the PRF insurance program as long as the rancher has the available capital to do so.

Correlation Matrices

Multicollinearity occurs when explanatory variables are highly correlated with each other and are of concern as it may reduce the precision of the results. For this study, concern for multicollinearity is especially present with the use of the CBV, premium rate, and loss ratio variables. We use the CBV and premium rate to determine the total premium payment value, with the CBV additionally used in the indemnity calculation. We use both indemnity and premium payments in the calculation of the loss ratio variable; therefore, we test for potential collinearity. However, it is worth noting the USDA-RMA argues, when rated correctly, the CBV should not be correlated with the premium paid or indemnity.

Additionally, we highly suspect a strong correlation between the LFP variables as the months eligible impact the size of the payments. Even though the LFP variables only account for the months during the grazing season and typically do not include the month of November, there is still a possibility the fall drought variable may be correlated with the LFP variables as it uses the same index. Corn prices and feeder prices are commonly highly correlated, as corn is a standard input for feeder cattle. Therefore, we check for this potential concern for all variables and show the results of the correlation matrix in tables 6.2.

Table 6.2: Correlation Matrix for Coverage Level and Participation Regression Variables

	CovL	CBV	LR	PR	FI	LFP	LP	FD	CP	FC
Coverage Level	1	--	--	--	--	--	--	--	--	--
County Base Value	0.11	1	--	--	--	--	--	--	--	--
Loss Ratio	-0.01	-0.04	1	--	--	--	--	--	--	--
Premium Rate	-0.05	0.18	0.18	1	--	--	--	--	--	--
Farm Income	0.07	0.06	-0.07	0.03	1	--	--	--	--	--
LFP Months	-0.03	0.04	0.34	0.15	-0.07	1	--	--	--	--
LFP Payments	-0.09	-0.01	0.28	-0.01	-0.05	0.71	1	--	--	--
Fall Drought	-0.04	0.14	0.34	0.19	-0.07	0.77	0.53	1	--	--
Corn Futures	0.12	-0.11	0.09	0.08	0.01	0.10	-0.02	0.12	1	--
Feeder Cattle Futures	0.03	0.07	0.2	0.00	0.01	0.09	0.04	0.04	0.57	1
	Part	CBV	LR	PR	FI	LFP	LP	FD	CP	FC
Participation	1	--	--	--	--	--	--	--	--	--
County Base Value	-0.27	1	--	--	--	--	--	--	--	--
Loss Ratio	0.20	-0.04	1	--	--	--	--	--	--	--
Premium Rate	0.39	0.18	0.18	1	--	--	--	--	--	--
Farm Income	-0.01	0.06	-0.07	0.03	1	--	--	--	--	--
LFP Months	0.16	0.04	0.34	0.15	-0.07	1	--	--	--	--
LFP Payments	0.14	-0.01	0.28	-0.01	-0.05	0.71	1	--	--	--
Fall Drought	0.16	0.14	0.34	0.19	-0.07	0.77	0.53	1	--	--
Corn Futures	0.16	-0.11	0.09	0.08	0.01	0.10	-0.02	0.12	1	--
Feeder Cattle Futures	0.01	0.07	0.2	0.00	0.01	0.09	0.04	0.04	0.57	1

SOURCES: The Risk Management Agency (RMA) records county indemnities, premiums, and subsidies used to calculate the loss ratios, as well, yearly county base values. Farm income is calculated by county income earned from farming operations from the Bureau of Economic Analysis (BEA) divided by total number of farms within a county from the National Agricultural Statistics Services (NASS). LFP data are provided by the Farm Service Agency (FSA). Drought monitor index data are also included to determine if fall drought conditions impact purchasing choices.

As expected, there is a high correlation between variables utilizing the USDM as LFP payments and months have a correlation of 0.71 and LFP months, and the fall drought variable has a correlation of 0.77. Due to the USDM variables' high correlation, we analyze these variables within the regressions separately. Feeder cattle and corn futures price also displays a high correlation with 0.57. Concerns of the CBV, premium

rate, and loss ratio variables appear not to be a source of concern as they prove to be weekly correlated. Excluding the USDM and futures price variables, multicollinearity does not appear to be problematic, with the correlation between all other variables less than 0.39.

CHAPTER SEVEN

EMPIRICAL RESULTS AND IMPLICATIONS

Tables 7.1 and 7.2 display the estimated impacts of changes in CBVs, previous year's producer paid loss ratios, premium rates, the loss ratio/premium rate interaction, and farm earned income on current year participation and coverage level choices in the PRF insurance program. The first column presents the ordinary least squares (OLS) estimates for both participation and coverage level regression results. The second column exhibits results controlling for unobserved heterogeneity between agricultural district fixed effects (as shown in equations 6.3 & 6.4).²⁴

Counties within agricultural districts may have commonalities that influence their decisions to participate or choose a particular coverage level (i.e. insurance agent density, PRF program education level). Therefore, we control for this potential correlation by using clustered standard errors at the agricultural district-level. Results from these tables indicate the CBV and premium rate/loss ratio interaction term have a significant impact on producers' acreage enrollment in the current year. However, producers' coverage level decisions appear to only be impacted by premium rates. This section will present in further detail results and discussion for participation regressions, coverage level

²⁴ A Hausman test was employed to test the significance of the fixed effect estimator and confirmed a fixed effect regression is the most appropriate model specification.

regressions, and regressions using additional variables such as futures price, LFP month eligibility, LFP payment, and fall drought conditions.

Table 7.1: Impacts on Participation in the PRF Program in the Western United States

	(1)	(2)
Intercept	0.131 (0.126)	1.177*** (0.124)
County Base Value	-0.014*** (0.002)	-0.008*** (0.002)
Premium Rate	1.418*** (0.390)	0.042 (0.332)
Loss Ratio _{t-1}	-0.099** (0.034)	-0.047* (0.021)
Premium Rate*Loss Ratio _{t-1}	0.689*** (0.175)	0.336* (0.137)
Farm Earned Income _{t-1} (logged)	0.006 (0.015)	-0.014 (0.012)
Fixed Effects	None	Ag District
Cluster	None	Ag District
N	434	434
R-Squared	0.331	0.736

Estimates are reported with t-statistics in parenthesis. P-values are reported based on a two-tailed test *p<0.10, **p<0.05 and ***p<0.01.

Dependent variable is participation measured as the proportion of acres enrolled in the PRF program out of the available pasture acres in a county.

Table 7.2: Impacts on Coverage Level Choice in the PRF Program in the Western United States

	(1)	(2)
Intercept	0.831*** (0.016)	0.833*** (0.024)
County Base Value	0.000* (0.000)	-0.000 (0.000)
Premium Rate	-0.022 (0.045)	0.126* (0.051)
Loss Ratio _{t-1}	0.005 (0.004)	0.002 (0.004)
Premium Rate*Loss Ratio _{t-1}	-0.025 (0.019)	-0.013 (0.019)
Farm Earned Income _{t-1} (logged)	0.003 (0.002)	0.000 (0.006)
Fixed Effects	None	Ag District Level
Cluster	None	Ag District Level
N	434	434
R-Squared	0.029	0.333

Estimates are reported with t-statistics in parenthesis. P-values are reported based on a two-tailed test *p<0.10, **p<0.05 and ***p<0.01.

Dependent variable is coverage level measured as a weighted average for each county (see data section for further description).

Participation Regression Results Discussion

We find evidence that increases in CBVs have a negative impact on counties enrolling additional acreage in the PRF program in the current year, indicating ranchers may display demand sensitivity to price changes in the program. Producer paid premiums and potential indemnity payments will increase when the CBV is increased, holding all else constant. While this increase may give a producer a higher payoff to cover damages when losses occur, an increased premium rate will also make the PRF program more expensive to insure in. These estimates suggest the average rancher may be more concerned with the affordability of the program rather than the perceived risk-reducing indemnity payments.

We attribute an increase in acreage enrollment in response to a lower CBV to producers viewing the program as more affordable and enrolling additional acreage at a reduced cost. This increase may also come from an increase in enrollment by lower-income or lower risk producers who can now afford to insure. Ranchers' ability to insure in the PRF program is constrained by available liquid capital, which makes the affordability of the program important. Premiums are functions of the premium rate and the liability. A lower CBV (which is used to compute the liability) will allow ranchers to lower their premium payments or make changes when they insure, such as choosing a higher coverage level, productivity factor, more expensive interval selection, or insure additional acres at the same premium price.

We analyze two of these choices in this thesis. Our results indicate that counties average coverage level selection do not show much variation, with the average coverage level choice being approximately 85% for most counties. Thus, we would not expect ranchers to change their coverage level choice. Studies have found the optimal interval selection for profit-maximizing producers are months when rainfall is the most variable. Therefore, we would not expect to see changes in interval selections when CBVs change (Carlson 2017; Westerhold 2018; Williams and Travis 2019). We do not analyze the changes to producers' choice in productivity factor; consequently, we cannot make any

predictions.²⁵ However, we find that a \$1 decrease in a CBV is associated with an increase in the proportion of acreage enrolled in the PRF program in a county by 0.8 percentage points. Although this estimate is small in magnitude, it can have a significant impact on counties that experienced substantial changes in CBVs. In 2016, CBVs for some California counties were increased by \$25.51. Therefore, this increase is estimated to have led to as much as a 20 percentage point decrease in acreage enrollment.²⁶ Conversely, some Oregon counties in 2018 experienced decreases in CBVs by \$21.70, which is estimated to have led to as much as a 17 percentage point increase in acreage enrollment. Table 7.3 displays a further summary of the estimated percentage point effect of CBV changes, which shows the maximum, minimum, and average estimated effects for each state (averaged across counties).

²⁵ Producers likely make adjustments to their price elections, which impact total liability when enrolling in the PRF program to reduce their total premium payment in the presence of either premium rate or CBV changes. Further research is needed to obtain precise estimates on how ranchers adjust their total liability in response to price changes. To estimate this relationship, data on the proportion of liability enrolled out of the total available liability would need to be used to represent participation.

²⁶ We urge caution in making strong inferences from these large changes to the CBVs, as our regression results estimate changes from marginal variation in the CBV. Therefore, the true effect of these large changes may be smaller or larger than the result estimates we present.

Table 7.3: Estimated Percentage Point Effect For CBV Changes (\$/Acre; Averaged Across Counties) – Years 2016-2020

	Max Reduction	Estimated Effect	Average Change	Estimated Effect	Max Increase	Estimated Effect
Arizona	-\$8.80	7.0%	-\$3.00	2.4%	\$4.80	-3.8%
California	-\$10.60	8.4%	\$1.66	-1.3%	\$25.51	-20.2%
Colorado	-\$17.30	13.7%	-\$0.50	0.4%	\$25.16	-19.9%
Idaho	-\$13.10	10.4%	-\$2.41	1.9%	\$7.60	-6.0%
Montana	-\$8.80	7.0%	\$0.40	-0.3%	\$8.30	-6.6%
Nevada	-\$1.20	1.0%	\$0.80	0.6%	\$7.10	-5.6%
New Mexico	-\$6.10	4.8%	-\$0.58	0.5%	\$6.90	-5.5%
Oregon	-\$21.70	17.2%	-\$1.51	1.2%	\$11.10	-8.8%
Utah	-\$3.90	3.1%	-\$1.27	1.0%	\$2.70	-2.1%
Washington	-\$5.80	4.6%	\$0.65	-0.5%	\$5.80	-4.6%
Wyoming	-\$5.00	4.0%	-\$2.15	1.7%	\$1.40	-1.1%

The coefficient estimate for the interaction term between the premium rate and the recent loss ratio is positive and significant both statistically and in magnitude. This result signifies counties, especially higher premium counties, respond strongly to recent losses. This result suggests that the average rancher may display memory anchoring in their participation decisions in the current year. Counties that on average receive indemnities higher than the initial premium payment in the previous year may be more likely to insure additional acreage in the current year as new or currently enrolling ranchers expect to have a similar outcome. However, the magnitude of this response varies by premium rate. Premium rates are generally estimated by incorporating the probability of experiencing low rainfall. Therefore, we expect higher premium rate counties to be at higher risk of losses attributed to low rainfall conditions. In the western United States, higher premium rate counties commonly have higher participation rates in the PRF program (Arizona, California, Nevada). Figure 7.1 displays the estimated effect of recent

losses on participation given low, medium, and high premium rates. This effect shows that the higher the previous year's loss ratio, and the higher the premium rate, the higher the participation.

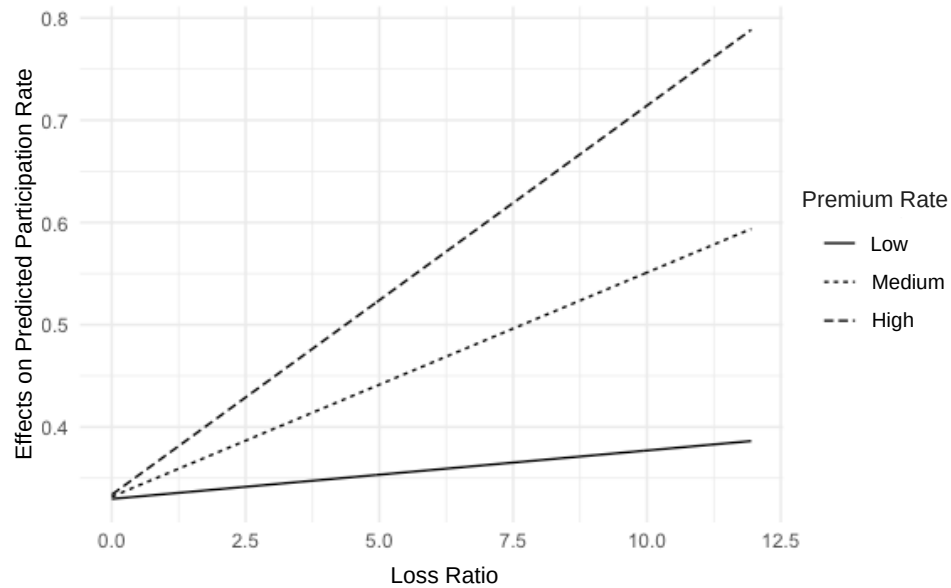


Figure 7. 1 The Predicted Marginal Effects of the Loss Ratio and Premium Rate on Participation

The premium rate appears to have a positive effect on participation, which is contradictory to our CBV finding, suggesting that a more expensive premium payment will lead to reduced participation. However, this result does not show statistical significance. Additionally, our data shows the highest enrolling counties to also have higher premium rates. However, when the data includes observations at the coverage and interval selection the sign of premium rate estimate does have a negative sign. Therefore, the premium rate estimate in this study does not provide strong evidence against the CBV

finding and further research is necessary to determine the true impact a premium rate change has on participation.

Contradictory to our hypothesis, the previous year's loss ratio appears to have a negative and significant impact on acreage enrollment. However, this coefficient is interpreted as the effect of the expected loss ratio when the premium rate is zero, which is not a possible premium rate for an insuring producer. On the other hand, the marginal effect (at all other explanatory variables mean) of the previous year's loss ratio is positive and statistically significant with an estimated effect of 2.1 percentage points on participation. This finding is congruent with our initial hypothesis that the higher the previous year's loss ratio, the higher the participation in the current year.

The results from the interaction term indicate counties at higher risk of experiencing low rainfall conditions are much more likely to have higher enrollment in the PRF program. Crop insurance studies have used this interaction term to conclude that this result indicates adverse selection in the program (Miranda 1991; Goodwin 1993). However, due to the nature of the PRF program, where historical data is used to determine indemnity thresholds, it is likely that both buyer and seller of the insurance product have similar amounts of information. Therefore, we cannot conclude there is adverse selection in the PRF program.

We find no empirical evidence that farm earned income has an impact on participation. Higher income from agriculture operations is expected to increase the available liquid capital of a producer, thus allowing them to purchase more PRF insurance protection. However, we find no significant evidence to support this claim. One

limitation to these data is the inability to separate income from ranching operations and farming operations as we expect the aggregation of the two could lead to imprecise estimates. Additionally, the BEA provides farm income estimates every year, but there is a concern for the consistency of the data as the BEA discloses data only during census years that are consistently based on census data and not interpolated or imputed (Kuwayama et al. 2019).

Coverage Level Choice Result Discussion

We obtain minimal meaningful evidence that changes in the programs CBVs, premium rates, previous year's loss ratios, or farm earned income has any impact on a counties average coverage level selection. An increased CBV or premium rate will lead to higher premium payments, thus making the program costlier. A more expensive premium may lead to a rancher reducing their coverage level, as a lower coverage level reduces the cost of premiums (Babcock 2015; Bulut 2016).

The premium rate is the only statistically significant coefficient, which displays a positive effect on coverage level choice. Previous research evaluating coverage level choices for crop insurance finds an increased premium rate is associated with a decreased coverage level (Bulut 2016; Boyd 2019). One potential reason for this contradiction is the fundamental differences between crop insurance and PRF insurance. Crop insurance evaluates claims at the individual level, taking into account farmers actual losses realized. PRF insurance on the other hand, uses an index as a proxy for losses. Therefore, there is more risk involved in enrolling in the PRF insurance program as a rancher is not guaranteed payment after a loss occurs. To reduce risk of not receiving an indemnity

ranchers may insure at the higher coverage levels. However, further research is needed to confidently determine the reasons for this incongruity in coverage level response to premium rates.

The most substantial limitation when analyzing coverage level determinants is the lack of variation among coverage level choices within the data. Ranchers' primarily enroll in either 75%, 85%, or 90% coverage levels, with some states reporting no acreage enrolled in either 70% or 80% (i.e., Idaho, Oregon, Washington) coverage levels. This behavior is consistent with expected utility maximization behavior. Expected utility maximization behavior explains a rancher will likely always insure at a higher coverage level to maximize their per acre subsidy and potential of triggering an indemnity. A higher coverage level choice will increase the probability of triggering an indemnity payment compared to a smaller coverage level. Thus highly risk-averse individuals will always choose the highest coverage levels. The PRF program base subsidy rates off of the coverage level selection. However, some coverage level selections offer the same subsidy rate (70% and 75%, 80% and 85%). An additional assumption made by expected utility theory is a rancher will not purchase a lower coverage level if a higher coverage has a higher per-acre subsidy (Babcock 2015). Thus, the incentive to enroll at the lower coverage level is minimal for livestock producers. As shown in table 7.4, when presented with this option, over 90% of acreage enrollment in the PRF program for 2018 was insured under the higher coverage level.

Table 7.4: Proportion of Acres Enrolled in the PRF Program in 2018 in Each Coverage Level With the Same Subsidy Rate

Coverage Level	Subsidy Rate	Proportion Acres Enrolled
70%	59%	7%
75%	59%	93%
80%	55%	3%
85%	55%	97%

NOTES: The proportion of acres enrolled in each coverage level was computed by dividing the acres insured in a particular coverage level by the sum of acres insured in coverage levels with the same subsidy rate.

Futures Prices Result Discussion

To control for market expectations impact, we include both the national feeder cattle and corn futures price for each year to our analysis. Tables 7.5 and 7.6 present the results for acreage participation and coverage level choices when including futures price variables. We find no evidence that feeder cattle futures price has any impact on participation, nor do futures prices impact coverage level decisions. The corn futures price shows a statistically significant and positive impact on acreage enrollment in the PRF program. Lower feedlot prices are generally correlated with higher corn prices (Stillman, Haley and Mathews 2009). Thus, the rancher may experience a reduced revenue. High corn prices can arise from a shortage in supply due to low levels of production attributed to either crop disease, pests, or poor weather conditions. A decreased supply of corn may cause price volatility in cattle markets and may increase the rancher's perceived market risk. An increase in risk may induce a rancher to purchase additional protection to help safeguard against all potential losses.

Table 7.5: Futures Price Variables Impact on Participation in the PRF Insurance Program

	(1)	(2)
Intercept	-0.350 (0.534)	1.114*** (0.134)
County Base Value	-0.006*** (0.002)	-0.008*** (0.002)
Premium Rate	0.155 (0.341)	0.082 (0.334)
Loss Ratio _{t-1}	-0.029 (0.024)	-0.0434* (0.0213)
Premium Rate*Loss Ratio _{t-1}	0.232 (0.150)	0.311* (0.139)
Farm Earned Income _{t-1} (logged)	-0.002 (0.012)	-0.015 (0.012)
Corn Futures Price	0.004** (0.001)	
Feeder Cattle Futures		0.000 (0.000)
Fixed Effects	Ag District	Ag District
Cluster	Ag District	Ag District
N	434	434
R-Squared	0.742	0.736

Estimates are reported with t-statistics in parenthesis. P-values are reported based on a two-tailed test *p<0.10, **p<0.05 and ***p<0.01.

Dependent variable is participation measured as the proportion of acres enrolled in the PRF program out of the available pasture acres in a county.

Table 7.6: Futures Price Variables Impact on Coverage Level Choice in the PRF Insurance Program

	(1)	(2)
Intercept	0.716*** (0.086)	0.824*** (0.029)
County Base Value	-0.000 (0.000)	-0.000 (0.000)
Premium Rate	0.135** (0.051)	0.132* (0.052)
Loss Ratio _{t-1}	0.003 (0.004)	0.003 (0.004)
Premium Rate*Loss Ratio _{t-1}	-0.021 (0.020)	-0.017 (0.020)
Farm Earned Income _{t-1} (logged)	0.000 (0.002)	0.000 (0.002)
Corn Futures Price	0.000 (0.000)	
Feeder Cattle Futures		0.000 (0.000)
Fixed Effects	Ag District	Ag District
Cluster	Ag District	Ag District
N	434	434
R-Squared	0.337	0.334

Estimates are reported with t-statistics in parenthesis. P-values are reported based on a two-tailed test *p<0.10, **p<0.05 and ***p<0.01.

Dependent variable is coverage level measured as a weighted average for each county (see data section for further description).

LFP and Drought Results Discussion

We analyze the impact of another livestock forage risk protection program in this thesis, along with the impact of a fall drought status during the final month of enrollment in the PRF program. Tables 7.7 and 7.8 display the results of the additional LFP and drought variables on participation and coverage level choices, respectively. Each variable was analyzed separately as correlation is detected between all three variables (see correlation matrix table 6.3).

Results from these regressions indicate only the LFP payment dollar amount has a statistically significant impact on participation, but not at a significant magnitude. Both programs are relatively new; therefore, there is little research on the impacts the two programs have on each other, but one study finds they may function as compliments (Carlson 2017). Given the LFP program requires no premium to be eligible, a rancher has little incentive not to use the program in addition to the PRF program. We hypothesize a ranchers enrollment in the PRF program in the current year will be impacted by the eligibility in the LFP program and the magnitude of a drought in the previous year as individuals generally take up more risk protection after severe losses. This thesis measures this effect by including both LFP variables and a fall drought dummy variable. From these results, a county that receives an LFP payment may be more likely to enroll additional acreage in the PRF program in the following year. However, we interpret these results with caution as the magnitude of this impact is relatively small.

Table 7.7: USDM Index Variables Impact on Participation in the PRF Insurance Program

	(1)	(2)	(3)
Intercept	1.178*** (0.124)	1.152*** (0.123)	1.175*** (0.124)
County Base Value	-0.008*** (0.002)	-0.008*** (0.002)	-0.008*** (0.002)
Premium Rate	0.015 (0.332)	0.021 (0.332)	0.030 (0.332)
Loss Ratio _{t-1}	-0.051* (0.021)	-0.060** (0.022)	-0.049* (0.021)
Premium Rate*Loss Ratio _{t-1}	0.347* (0.136)	0.370** (0.137)	0.341* (0.135)
Farm Earned Income _{t-1} (logged)	-0.014 (0.012)	-0.011 (0.011)	-0.014 (0.012)
LFP Month Eligibility _{t-1}	0.005 (0.005)		
LFP Payment _{t-1}		0.000* (0.000)	
Fall Drought _{t-1}			0.012 (0.027)
Fixed Effects	Ag District	Ag District	Ag District
Cluster	Ag District	Ag District	Ag District
N	434	434	434
R-Squared	0.737	0.741	0.736

Estimates are reported with t-statistics in parenthesis. P-values are reported based on a two-tailed test *p<0.10, **p<0.05 and ***p<0.01.

Dependent variable is participation measured as the proportion of acres enrolled in the PRF program out of the available pasture acres in a county.

Table 7.8: USDM Index Variables Impact on Coverage Level Choice in the PRF Insurance Program

	(1)	(2)	(3)
Intercept	0.833*** (0.024)	0.845*** (0.025)	0.834*** (0.025)
County Base Value	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Premium Rate	0.123* (0.051)	0.128* (0.051)	0.130* (0.051)
Loss Ratio _{t-1}	0.002 (0.004)	0.003 (0.004)	0.003 (0.004)
Premium Rate*Loss Ratio _{t-1}	-0.012 (0.019)	-0.016 (0.018)	-0.015 (0.019)
Farm Earned Income _{t-1} (logged)	0.000 (0.002)	-0.000 (0.002)	-0.000 (0.002)
LFP Month Eligibility _{t-1}	0.001 (0.001)		
LFP Payment _{t-1}		-0.000 (0.000)	
Fall Drought _{t-1}			-0.004 (0.004)
Fixed Effects	Ag District	Ag District	Ag District
Cluster	Ag District	Ag District	Ag District
N	434	434	434
R-Squared	0.334	0.337	0.335

Estimates are reported with t-statistics in parenthesis. P-values are reported based on a two-tailed test *p<0.10, **p<0.05 and ***p<0.01.

Dependent variable is coverage level measured as a weighted average for each county (see data section for further description).

Robustness Check

Tercile Regression Results

To determine if our participation results are consistent across different CBV changes, we subset our dataset into three groups: Low CBV observations (\$3.60 to \$13.50), medium (\$13.50 to \$21.10), and high (\$21.10 to \$49.10). A low CBV will likely lead to a lower up-front cost of enrolling in the PRF program. Thus, we expect that the higher the CBV, the costlier the premium payment. Table 7.9 displays the participation

regression results for each group. We split our data into three bins of observations (based on the CBV value) to run the least square dummy variable (LSDV) model. Overall, results are consistent with our original findings, but the high CBV group shows no significant results. Additionally, it is notable that the medium CBV group shows evidence of being the most responsive group to CBV changes, with a \$1 increase in CBV leading to a 4.5 percentage point decrease in available acreage enrolled in the PRF program.

Table 7.9: Tercile Regression Results for Participation in the PRF Program

	Low	Medium	High
Intercept	1.489*** (0.232)	1.122** (0.360)	0.273 (0.166)
County Base Value	-0.040*** (0.011)	-0.045* (0.020)	-0.005 (0.003)
Premium Rate	0.050 (0.705)	-0.497 (0.897)	0.411 (0.362)
Loss Ratio _{t-1}	-0.071* (0.036)	-0.126 (0.067)	0.047 (0.040)
Premium Rate*Loss Ratio _{t-1}	0.559* (0.244)	0.968* (0.469)	0.341 (0.135)
Farm Earned Income _{t-1} (logged)	-0.026 (0.024)	-0.010 (0.013)	-0.008 (0.010)
Fixed Effects	Ag District	Ag District	Ag District
Cluster	Ag District	Ag District	Ag District
N	150	139	145
R-Squared	0.803	0.770	0.541

Estimates are reported with t-statistics in parenthesis. P-values are reported based on a two-tailed test *p<0.10, **p<0.05 and ***p<0.01.

Dependent variable is participation measured as the proportion of acres enrolled in the PRF program out of the available pasture acres in a county.

Although these results are consistent with our initial findings, we urge caution when interpreting them as each sample is limited in size. Additionally, the distribution of these groups is of concern. The medium groups show the least amount of range in CBVs, suggesting there is not a large amount of variation in price changes. In contrast, the high

CBV group shows the most variation in CBVs, but as the CBVs get larger, there is a drastic decline in observations (Figure 7.2).

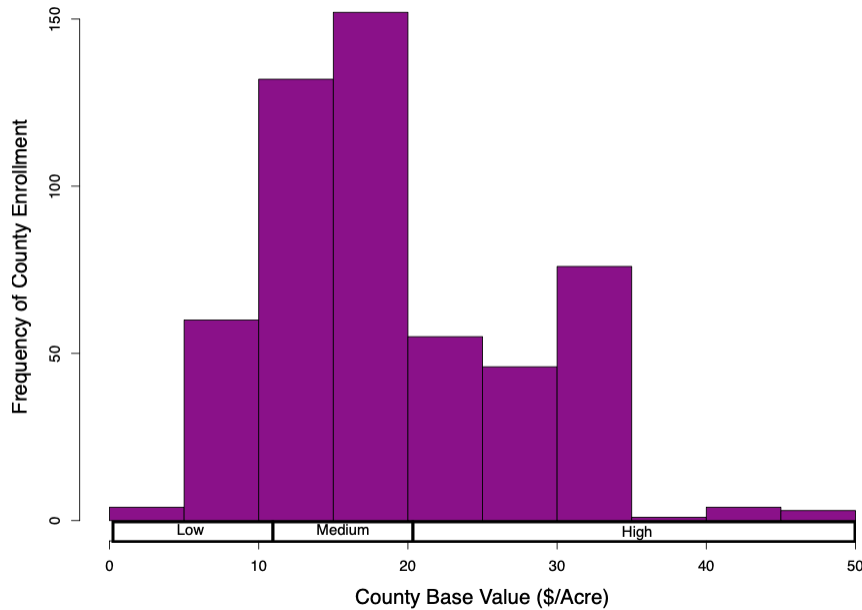


Figure 7.2 Distribution of County Observations For Each CBV
SOURCE:USDA-RMA

Seemingly Unrelated Regression Equation Results

To check the robustness of our LSDV results (table 7.1 and 7.2), we ran a seemingly unrelated regression equation (SURE) model. Decisions to participate in the PRF program and choose a coverage level are likely influenced simultaneously by unobservable factors. Thus we would expect the two equations (participation and coverage level regressions) would have error terms that are related. Table 7.10 shows the results of this model with columns (1) and (2) presenting the results of the LSDV regressions and columns (3) and (4) showing the results from the SURE estimation.

Table 7.10: Seemingly Unrelated Regression Equation (SURE) Model Results

	(1)	(2)	(3)	(4)
Intercept	1.177*** (0.133)	0.748*** (0.069)	1.176*** (0.133)	0.736*** (0.077)
County Base Value	-0.008*** (0.002)	-0.000 (0.000)	-0.008*** (0.002)	-0.000 (0.000)
Premium Rate	0.041 (0.352)	0.090* (0.040)	0.054 (0.352)	0.098* (0.044)
Loss Ratio _{t-1}	-0.047* (0.023)		-0.046 (0.023)	
Premium Rate*Loss Ratio _{t-1}	0.336** (0.124)		0.329** (0.124)	
Farm Earned Income (logged)	-0.014 (0.011)		-0.014 (0.011)	
Corn Futures		0.000 (0.000)		0.000 (0.000)
LFP Eligibility _{t-1}		0.000 (0.000)		0.000 (0.001)
Fixed Effects	Ag District	Ag District	Ag District	Ag District
Cluster	Ag District	Ag District	Ag District	Ag District
SURE Model	No	No	Yes	Yes
Intercept	Participation	Coverage Level	Participation	Coverage Level
N	434	434	434	434
Multiple R-Squared	0.736	0.342	0.735	0.335
Adjusted R-Squared	0.705	0.276	0.705	0.258

Estimates are reported with t-statistics in parenthesis. P-values are reported based on a two-tailed test *p<0.10, **p<0.05 and ***p<0.01.

Dependent variable (1) and (3) is participation measured as the proportion of acres enrolled in the PRF program out of the available pasture acres in a county.

Dependent variable (2) and (4) is coverage level measured as a weighted average for each county (see data section for further description).

Overall, the results from the SURE estimation show small changes in the coefficient and standard error estimates. The correlation between the two error terms is estimated to be negative 0.057. Along with the relatively small estimated correlation, we ran a Breusch-Pagan test for error independence, which indicated no statistically significant correlation between the two equations error terms. Therefore, we conclude there is no statistical difference between the SURE model and LSDV model estimation.

Summary of Results

This empirical analysis's primary purpose is to determine and understand the factors influencing ranchers' participation and coverage level choices in the PRF insurance program and ranchers' sensitivity to price changes. Results indicate CBV and premium rate changes, conditional on the previous year's loss ratio, have significant impacts on counties acreage participation in the PRF program. These results are consistent and robust across other model specifications that use alternative methods for dependent variable outliers and CBV censoring. However, we find no reliable evidence that future market price expectations, previous year's drought conditions, or the LFP program impact a rancher's decision to enroll in the PRF insurance program.

Results from the LSDV model indicate that CBVs have a negative relationship with participation as the higher the CBV, the more expensive the program is to insure in. This estimated impact is relatively small for many counties that experienced modest changes to their CBVs in the last four years. However, some counties experienced substantial CBV changes and are estimated to see decreases or increases in participation as high as 20 percentage points.

We find evidence of potential memory anchoring when analyzing the impacts of previous year's loss ratio on participation. This result suggests a county, that on average experiences higher indemnities in relation to the premium payments in the previous year, will likely experience an increased acreage enrollment in the current year. Additionally, our results indicate counties at higher risk of losses related to low rainfall are much more likely to enroll in the PRF program.

While our results find very little statistically significant evidence towards producers' coverage level determinants, we do find evidence to explain their coverage choice behavior. Coverage level decisions show minimal variation. Thus, we find producers are acting consistently with expected utility maximization theory by enrolling at the higher coverage level selections. Additionally, we find that ranchers almost always enroll at a higher coverage level when presented with the same subsidy rate.

SECTION EIGHT

CONCLUSION

Insurance product availability for livestock producers has been expanding in the last two decades. With climate conditions posing a considerable threat to the sustainability of livestock producers' operations, insurance programs may become an important risk mitigation tool. However, there must be sufficient demand for an insurance program to continue to be offered. Demand for insurance is commonly affected by the programs affordability and risk mitigation effectiveness. This study primarily focuses on the former. With the PRF program being the only insurance program to insure ranchers' perennial pasture it is important to identify the factors that influence ranchers' insurance choices. Therefore, this study provides evidence in determining factors that influence participation and how recent changes that affect the premium payments have impacted participation.

The PRF insurance program has made many changes that fundamentally impact the program's premium payments. To my knowledge, no study to date has investigated how changes that affect the PRF programs premium payment are associated with ranchers' participation decisions. This study provides evidence that increases in county base values (CBVs) may have a negative impact on rancher's participation in the PRF program. This result suggests the lower the CBV, the less expensive the premium payment, *ceteris paribus*, which may allow more people to enroll and existing customers to increase their acreage insured.

This study also finds evidence that participants who are at lower risk of experiencing low rainfall conditions may be more responsive to price changes than higher-risk participants. From this result we would expect systematic increases to all premium rates may lead to lower participation among lower-risk ranchers. Additionally, we find evidence that higher risk participants may be more responsive to recent losses compared to lower risk participants. Recent losses may serve as a mental reference point for ranchers' enrolling in the PRF program. Therefore, these results provide evidence that producers might display memory anchoring when making decisions. This indicates that counties, which on average receive a large indemnity in relation to their premium payment, might expect to have the same outcome in the current year and continue to enroll or increase enrollment. On the other hand, if a rancher does not feel the indemnity they received was adequate to cover losses realized they may be deterred from enrolling again.

Results evaluating coverage level decisions indicate little evidence that the price, previous year's losses, previous year's drought condition, or future expectations have any significant impact. The PRF insurance program offers six coverage level options to participants. Of those options, participants most commonly select the two highest selections, and when presented with two coverage levels with the same subsidy rate, they almost always select the higher coverage level. This behavior is consistent with expected utility maximization theory, which tells us a producer will always choose the highest coverage level to maximize their chance of an indemnity and to maximize their per acre

subsidy. Additionally, this theory tells us that a producer will likely never choose a lower coverage level when presented with the same subsidy rate.

This study provides evidence for factors that influence ranchers' decisions to participate and select coverage levels. However, with the program experiencing substantial changes to its participation and structural functioning's (i.e. indexes used, availability, CBV and premium rate changes), we advise caution in these recommendations, as to the number of observations limits this study. We recommend further research to evaluate the impact of future years' price changes on participation in order to confirm the findings of this study. However, this thesis provides a crucial first step in determining factors that affect purchasing decisions in the PRF program. Identifying factors that motivate ranchers' decision to participate in this program is essential for program designers to make a product that is and continues to be demanded.

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APPENDICES

APPENDIX A

PREMIUM RATE TABLES

Table A.1 Premiums Paid Per Acre and Liability (Averaged Across Counties and Coverage Levels) – Years 2016-2019

State	Premium Per Acre				Premium Per Liability			
	Mean	Min	Max	S.D	Mean	Min	Max	S.D
Arizona								
2016	5.96	3.25	8.60	1.75	0.28	0.24	0.35	0.03
2017	4.69	2.23	6.17	1.06	0.28	0.19	0.35	0.04
2018	4.21	2.49	5.50	0.90	0.29	0.25	0.35	0.03
2019	2.49	1.55	3.33	0.54	0.30	0.27	0.35	0.03
California								
2016	5.97	4.06	8.66	1.26	0.29	0.23	0.34	0.03
2017	5.30	3.58	7.14	0.99	0.28	0.22	0.32	0.03
2018	6.25	3.74	9.58	1.68	0.29	0.21	0.33	0.03
2019	6.78	3.50	11.57	2.17	0.29	0.22	0.36	0.03
Colorado								
2016	6.02	2.80	9.62	2.01	0.19	0.13	0.24	0.02
2017	5.49	3.00	9.41	1.69	0.20	0.14	0.25	0.03
2018	3.76	2.27	6.04	0.97	0.20	0.13	0.25	0.03
2019	2.99	2.20	3.93	0.46	0.20	0.15	0.25	0.03
Idaho								
2017	7.32	7.32	7.32	0.00	0.24	0.24	0.24	0.00
2018	4.25	2.61	5.36	0.89	0.22	0.17	0.26	0.03
2019	4.84	3.61	7.92	1.09	0.22	0.17	0.28	0.03
Montana								
2016	2.50	1.40	3.80	0.65	0.18	0.13	0.21	0.02
2017	2.38	1.12	3.98	0.67	0.17	0.12	0.24	0.02
2018	2.25	0.91	4.25	0.85	0.18	0.14	0.22	0.02
2019	1.87	0.78	3.26	0.54	0.18	0.14	0.24	0.02
Nevada								
2016	1.78	1.36	2.10	0.30	0.29	0.26	0.33	0.03
2017	1.53	1.11	2.00	0.32	0.30	0.27	0.35	0.03
2018	2.82	2.51	3.13	0.44	0.29	0.27	0.30	0.02
2019	3.09	2.62	3.44	0.36	0.28	0.24	0.32	0.03

SOURCE: USDA-RMA Summary of Business

Table A.1 Continued. Premiums Paid Per Acre and Liability (Counties by State) – Years 2016-2020

State	Premium Per Acre				Premium Per Liability			
	Mean	Min	Max	S.D	Mean	Min	Max	S.D
New Mexico								
2016	2.80	1.78	3.93	0.48	0.24	0.19	0.30	0.03
2017	2.90	1.73	3.77	0.58	0.25	0.18	0.29	0.03
2018	3.67	2.47	4.50	0.62	0.25	0.22	0.29	0.03
2019	2.83	1.98	3.50	0.48	0.26	0.22	0.30	0.03
Oregon								
2016	7.42	4.49	10.71	2.59	0.22	0.19	0.27	0.03
2017	7.50	4.95	12.77	2.36	0.23	0.19	0.29	0.03
2018	5.62	3.56	9.26	2.12	0.23	0.19	0.29	0.03
2019	6.41	3.35	13.78	2.81	0.22	0.17	0.27	0.03
Utah								
2016	2.20	2.03	2.38	0.25	0.19	0.18	0.19	0.01
2017	2.16	1.76	2.78	0.38	0.21	0.18	0.25	0.03
2018	2.15	1.79	2.91	0.45	0.22	0.18	0.28	0.04
2019	1.59	0.96	2.38	0.44	0.22	0.18	0.28	0.03
Washington								
2016	8.44	8.33	8.54	0.15	0.24	0.24	0.24	0.00
2017	6.86	5.24	8.57	1.65	0.24	0.18	0.27	0.04
2018	6.88	4.81	10.20	1.79	0.24	0.18	0.30	0.04
2019	7.70	5.19	10.22	1.56	0.25	0.19	0.30	0.03
Wyoming								
2016	2.42	1.66	4.41	0.78	0.15	0.13	0.19	0.02
2017	2.23	1.52	3.36	0.55	0.17	0.14	0.21	0.02
2018	2.21	1.66	3.51	0.55	0.17	0.15	0.19	0.02
2019	1.66	1.23	2.21	0.37	0.18	0.15	0.19	0.01

SOURCE: USDA-RMA Summary of Business

APPENDIX B

OTHER VARIABLES CONSIDERED

Satellite density was initially considered for the regression equation as a proxy for the accuracy of the PRF rainfall index in correlations between low precipitation and actual yield losses, but was removed as the data is not an accurate representation of the use of the indexes for the PRF insurance program. The RMA uses the closest four reporting precipitation satellites in determining a grids indemnity payout. However, not all satellites are in use at all times, consequently satellites used by the RMA change frequently and may not be close to a livestock producers' insured acreage (USDA-RMA 2017a). We remove the average drought occurrences at each drought level due to the collinearity with the LFP data. LFP uses the drought monitor index to determine the months eligible and payments made. Therefore these variables account for droughts during the grazing season months. Besides, we account for droughts during the fall by adding a binary variable for the existence of a drought occurring in November, which is the last month producers can enroll in the PRF program.