Impact of droughts on farm debts: Empirical evidence from New Zealand

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Abstract

Exploring the relationships among climate change, agriculture, and financial markets is a contemporary issue in economics, with relatively little empirical work done thus far. This paper intends to extend the literature by empirically testing the relationships between droughts and farm debt by employing microeconomic modeling to quantify how past droughts (as measured by the latest and improved version of New Zealand Pasture Growth Index-NZPGI) impact farms' debt (measured in terms of real debt values and debt ratios). Data from the National Institute of Water and Atmospheric Research Ltd (NIWA) and Stats New Zealand Longitudinal Business Database (LBD) is used to test our model. Our results show a statistically significant positive impact of droughts on short-term and long-term debts of dairy farming and short-term debt of sheep and beef farming.

Keywords: Droughts, farm debt, NZPGI, dairy farming, sheep and beef farming, New

Zealand

1. Introduction

In the age of climate change, countries have placed much focus on global drought scenarios. There are successive projections from the National Institute of Water and Atmospheric (NIWA), New Zealand, of how climate change may lead to droughts. These projections are based on past data that reveal that about 85 percent of New Zealand districts were affected by droughts throughout 2007-2016. The predictions thus show an increase in the severity of drought in most areas. Therefore, the frequency and intensity of drought are expected to expand the size of drought-hit regions (NIWA, 2017), which can severely affect the economy. Statistics reveal that the 2008 drought cost over $US 1.5 billion (Butcher & Ford, 2009), and the 2013 drought lowered the real annual GDP by 0.6 percent (Kamber, McDonald, & Price, 2013).

Droughts generally lead to a reduction in agriculture production, mainly pasture-based and crop productions in various countries, for example, Australia (Edwards, Gray, & Hunter, 2009; Tran, Stoeckl, Esparon, & Jarvis, 2016) and New Zealand (Timar & Apatov, 2020). But in contrast, droughts may also lead to better agricultural productivity (Kingwell & Xayavong, 2017; Pourzand, Noy, & Sağlam, 2020). Moreover, there is emerging evidence of debts positively impacting agricultural productivity (Afangideh, 2009; Brehanu & Fufa, 2008; Chisasa & Makina, 2013; Guirkinger & Boucher, 2008; Harris, Johnson, Dillard, Williams, & Dubman, 2009) and banks increasing their agricultural debt in drought-affected years (De & Vij, 2012). The debts can help to smooth income between financially good and difficult years (Greig, Nuthall, & Old, 2019; Ma, Renwick, & Zhou, 2020). Statistics from New Zealand also reveal that the total farm debt has increased by 270 percent over the past twenty years (RBNZ, 2019).

The farm debt may be a missing link and an important factor between drought and farm productivity/financial performance. Therefore, this paper will explore the relationship between droughts and farm debts, using NIWA and Statistics NZ's LBD data. The rest of the paper is organized as follows: Literature background presents the literature review and the paper's contribution towards the existing body of literature in section 2. Methods present the description of our data, variables, and model in section 3. The main results are summarized in section 4 and the conclusion is in the last section

2. Literature background

Literature is scarce on the financial impact of droughts in New Zealand. Prior research testing the impact of droughts on agricultural farm business has revealed some contradictory findings. For example, Edwards et al. (2009) found that droughts negatively impacted farmers' agricultural production in Australia. Lawes and Kingwell (2012) found that droughts negatively altered the business indicators (business equity, operating profit/ha, return on capital, and the debt-to-income ratio) of the Australian farms under study. However, few farms managed to improve their equity position post-droughts. Tran et al. (2016) found that drought-affected properties earn about half as much as other 'similar' properties in Northern Australia. Timar and Apatov (2020) found a positive impact of droughts on dairy farms’ gross output and net profit, and a negative impact on current loans and intermediate expenditures of dairy farms in New Zealand.

In contrast, Kingwell and Xayavong (2017) demonstrated that consecutive years of drought had a significant positive effect on the operating profit per hectare and retained profit per hectare of farms in Australia. Moreover, and more recently, Pourzand et al. (2020) found that drought events have positive impacts on dairy farms' revenue and profit in the year of the drought in New Zealand. The contradictory findings of the aforementioned studies lead us to think that there may be a missing link in the relationship between drought and farm productivity/financial performance. We have reasons to believe that farm debt may be that missing link and an important factor in the aforementioned relationship(s). We, therefore, look at another stream of research exploring climate change, debt, and agricultural output in the following paragraph:

Prior research shows that debt has a significant impact on agricultural output. For example, Afangideh (2009), used the simulation approach and data from 1970 – 2005 from Nigeria to demonstrate that bank lending positively influenced real agricultural output. Similarly, Guirkinger and Boucher (2008) observed that credit constraints lower agricultural output value in Peru. Brehanu and Fufa (2008) observed that an increase in access to credit by small-scale farmers is one way to enhance agricultural productivity in Ethiopia. Chisasa and Makina (2013) found that bank credit positively impacts agricultural output in South Africa. Moreover, a report on The Debt Finance Landscape for US Farming and Farm Businesses shows farm debt level has risen in the face of decreasing net farm income with hog, dairy, and poultry producers, on average, more leveraged than other farms; these highly leveraged are also the most profitable ones (Harris et al., 2009). Evidence from mostly developing countries, therefore, reveals that debt indeed positively affects agricultural productivity.

The most recent evidence from developed countries has shown different results for the association between farm debts and farm performance. For example, Ma et al. (2020) show that the debt ratio significantly decreases both the technical efficiency of dairy farms and return on assets in New Zealand. They reveal the time-specific effects that a high debt ratio increased dairy productivity between 2005 and 2009, whereas it decreased dairy productivity between 2011 and 2014. Whereas earlier different results were reported by Mugera and Nyambane (2015) for short-term and long-term debt effects on farm technical efficiency using evidence from Broadacre farms in Western Australia. They found a positive relationship of farm technical efficiency to short-term debt, tax liability, and capital investment, but a negative association to off-farm income-generating activities. But they did not found the affect of Long-term debt on production efficiency and returns on assets.

Furthermore, prior literature has explored farmers' access to debt as a potential climate change adaptation strategy (Akter & Fatema, 2011; Botzen & Van Den Bergh, 2008; The World Bank, 2012; World Food Programme & The International Fund for Agricultural Development, 2011). For example, Abraham and Fonta (2018) examined climate change and financing adaptation by farmers in northern Nigeria. Their results show a significant relationship between farmers' perceived exposure to climate change and their need for credit. Prior literature, however, provides limited evidence on the potential impact of droughts on farm debt. For example, De and Vij (2012) informed that banks increase agricultural debt in drought-affected years compared to years of normal rainfall in India. In contrast, Collier (2013), in his doctoral dissertation in Peru's context, informed that disasters dramatically hamper the ability of financial intermediaries to lend after an event, increasing the cost of the disaster and delaying recovery.

Therefore, we attempt to extend this line of inquiry by proposing and empirically testing the impact of droughts on farm debt in New Zealand's context. In the following sub-section, we discuss the current state of drought research, the various drought measures proposed and tested in the literature, and how the measure of drought we are using (i.e. NZPGI) differs from others, and how our measure is unique and ideal in New Zealand's context.

Drought measures and concepts

The impacts of droughts on agricultural yield vary during the crop-growing period, and farmers use coping strategies to regain pre-drought levels of production (Pourzand et al., 2020). Therefore, it remains difficult to adequately define, identify, and measure droughts due to their complex nature. Droughts are defined under five different dimensions: including metrological, soil moisture, hydrological, and socioeconomic and environmental droughts (OECD, 2016). All these interlinked dimensions defined the drought conditions as less rainfall, low level of soil moisture, and modified water cycles due to human activities. The characteristics of metrological and soil moisture droughts link the agriculture droughts by the following definition:

"Agricultural drought links the diverse characteristics of meteorological drought to agricultural impacts which focus on precipitation shortages, differences between actual and potential evapotranspiration, and soil moisture deficits" (American Meteorological Society, 1997).

Mishra and Singh (2010) in their review paper inform that "a drought index is a prime variable for assessing the effect of the drought and defining different drought parameters, like intensity, duration, severity and spatial extent. It should be noted that a drought variable should be able to quantify the drought for different time scales for which a long time series is essential. The most commonly used time scale for drought analysis is a year, followed by a month. Although the yearly time scale is long, it can also be used to abstract information on the regional behavior of droughts. The monthly time scale seems to be more appropriate for monitoring the effects of a drought in situations related to agriculture, water supply, and groundwater abstractions (Panu & Sharma, 2002). A time series of drought indices provides a framework for evaluating drought parameters of interest". Several different indices have been developed to quantify a drought. Table 1 summarizes them:

Table 1: Drought indices

Indices	**References**
Palmer drought severity index (PDSI)	Palmer (1965)
Rainfall anomaly index (RAI)	Van Rooy (1965)
Deciles	Gibbs and Maher (1967)
Crop moisture index (CMI)	Palmer (1968)
Bhalme and Mooly drought index (BMDI)	Bhalme and Mooley (1980)
Surface water supply index (SWSI)	Shafer and Dezman (1982)
National rainfall index (NRI)	Gommes and Petrassi (1994)

Standardized precipitation index (SPI)	McKee, Doesken, and Kleist (1993)
	McKee (1995)
Reclamation drought index (RDI)	Weghorst (1996)
The soil moisture drought index (SMDI)	Hollinger, Isard, and Welford (1993)
Crop-specific drought index (CSDI)	S. Meyer and Hubbard (1995)
Corn drought index (CDI)	J. L. Meyer and Pulliam (1992)
Soybean drought index (SDI)	S. Meyer and Hubbard (1995)
Vegetation condition index (VCI)	Liu and Kogan (1996)
New Zealand Drought Index (NZDI)	(NIWA, 2017)

We used NZPGI as an indicator of drought conditions. The pasture models have provided valuable insights into agricultural drought severity. For example, Weier and Herring (2000) and NASA (2000) used the Normalized Difference Vegetation Index (NDVI), which considers reduced plant growth as a drought indicator. The NZPGI projects and measures grass growth based on radiative energy, soil moisture, and temperature potential for New Zealand's dairy regions are driven by National Climate Station Network (NCSN) (NZX, 2019). The values of NZPGI lie between 0 and 100 in a unit of kg of dry matter per day. The values correspond to the amount of grass expected to grow in a "normal" hectare of farmland. The lower values indicate no or less grass growth, and the upper values indicate ideal conditions or more growth of grass.

There are two versions of NZPGI developed by NIWA. The original/old version of NZPGI was based on simple process modeling. The new version of NZPGI is subject to some empirical calibration. The older version assigned equal weights on measuring factors (radiative energy, soil moisture, and temperature), whereas the revised version was improved by re-weighting the factors. The regression model had scaling adjustments to the various components of the NZPGI model that is much better at predicting high-growth conditions.

Our study used a unique indicator of drought, which we believe is an ideal one in New Zealand's context: The NGPGI. We ask: *Why is drought important for New Zealand's agriculture?* Previously, The Ministry for the Environment identified drought as one of the major constraints to pasture grazing in New Zealand (MfE, 2001). A recent study by Pourzand et al. (2020) informs that drought affects pasture in New Zealand. Therefore, we will use an indicator measuring pasture growth (NGPGI by NIWA) rather than a drought index (for example, NZDI by NIWA). Our indicator of drought makes more sense because our focus is on dairy farming and sheep/beef farming; pasture reliant farms.

2.1 Agriculture sector in New Zealand

Agriculture is an important sector of the New Zealand economy. It contributes 4 percent directly to GDP and 4 percent indirectly. It contributes the maximum to the export sector, which is around 40 percent of the total (NZ Govt., 2016). The industry contributes to employment and inputs to secondary industries. Dairy farming is the primary sub-sector of the agricultural sector, followed by beef and sheep farming and horticulture (NZ Govt., 2016). The farm systems are dependent upon resources, animals, people, and businesses to be successful. The resources include pasture growth, supplementation, and nitrogen use efficiency. Any changes in resources may affect the farm business in terms of profitability, capital reserves, and debt portfolio.

2.2 Drought risks and measures in New Zealand

NIWA defines droughts as a deficit in rainfall, restricting human activities like farming (NIWA, 2019). Ministry for Prime Industries (MPI) of New Zealand classifies droughts into three main adverse events: localized, medium-scale, and large-scale, based on the magnitude of an event and the ability to prepare and capacity to cope with it. Their impact depends upon the frequency, magnitude, and severity of droughts. New Zealand has experienced the 2013 drought, recorded as one of the most extreme disasters that affected South Island's west coast and the whole North Island of the country.

Risks:

New Zealand is experiencing a change in the regional rainfall patterns over the past fifty years. According to the Ministry for Environment and Stats New Zealand report on "Our atmosphere and climate 2017," New Zealand had more dryer soils at seven sites out of a total of thirty sites for 1972-2016. The drought-prone regions are expected to increase due to changes in rainfall patterns and rising temperatures (MfE and StatsNZ, 2017). The west part of the country is predicted with increasing rainfall during spring and winter, whereas the east and north are predicted with decreasing trends during the same seasons. However, the west and central north island are expected to be drier during the summer, and the east part will have increased rainfall during summer (MfE, 2018). The glaciers of New Zealand are melting at a rate of 25% over the last twenty years. This phenomenon will affect the flow of water in rivers and subsequently have a significant consequence on irrigation.

The 2013 Drought: New Zealand had experienced the most extreme drought in 2013 over the past forty-one years, affecting the southern Northland, South Auckland, Waikato, Bay of Plenty and the Central Plateau, Wairarapa, Rangitikei, Ruapehu, Gisborne, and Hawke's Bay and north and west part of the South Island (NIWA, 2013).

Northland: The most frequently drought-affected region of New Zealand. Four adverse drought events hit the region during 2007-2017 (Mol, Tait, & Macara, 2017).

The Hurunui drought: The eastern part of the Hurunui district was seriously affected by the longest drought of history from 2015-16 and lasted for two winters (Mol et al., 2017).

Moreover, the El Niño Southern Oscillation cycle occurs every two to seven years and lasts around a year, which can lead to more droughts in the east (MfE and StatsNZ, 2017). The regional climate modeling results projected an increased drought severity in most parts of the country except for West Coast, Southland, and Taranaki-Manawatu (MfE, 2018)

Measures:

The changes in climate extremes can have an impact on the agriculture sector in New Zealand. More specifically, droughts can have economic, social, and environmental impacts in New Zealand. Therefore, farmers in New Zealand have to manage the increasing risks associated with droughts events. The eastern region of New Zealand is more prone to severe and frequent droughts (NZ Govt., 2016). NIWA had introduced a drought monitoring system; an index called the New Zealand Drought Index (NZDI), to track drought conditions around different geographical areas of New Zealand.

2.3 Agricultural debt trend in New Zealand

The total farm debt in New Zealand is $62.8 Billion, which has increased by 270 percent over the past twenty years (RBNZ, 2019). The agriculture sector debts counted for 14 percent of total bank lending (RBNZ, 2019). The significant classifications of agriculture sector debts are dairy, sheep and beef, and horticulture. The dairy sector debt contributes the maximum to the farm debts, and dairy farmers are more vulnerable to financial conditions in terms of an increased level of non-performing loans (RBNZ, 2019).

According to the economic survey of Dairy New Zealand, the term liabilities (including borrowings from families) of the dairy farms have increased by 69 percent from 2008-09 to 2017-18. In contrast, the farm size is increased by 17 percent only. According to debt to asset distribution, 24 percent of farmers hold more than 70 percent debt to asset ratio, and only 4% of farmers have more than 90 percent debt to asset ratio (DairyNZ, 2018). These basic statistics of debt trends in New Zealand signals the need for empirical research to find any connections between farm debts and weather conditions like drought.

3. Methods

3.1 Data

We used two major sources of datasets for our micro-level study. The first source is the NIWA Research Ltd. of New Zealand, and the other main source is Statistics New Zealand Longitudinal Business Data (LBD).

National Institute of Water and Atmospheric (NIWA)

National Institute of Water and Atmospheric Research Ltd (NIWA) is a research institute of New Zealand established to safeguard the country's environments and aquatic resources from climate hazards by providing economic value and sustainable management (NIWA, 2020). The Data on the latest version of NZPGI, our main independent variable, is collected from NIWA from 1972 to the latest. The Data is available daily, which can be converted to the required time scale of monthly, quarterly or annual averages according to the need to measure pasture growth at the spatial level.

The study of agriculture droughts is derived from different drought indices combining soil moisture, temperature, and precipitation (Mishra & Singh, 2010). As per our knowledge, this study is the first one to use NZPGI as a drought indicator; hence we haven't found any well-defined threshold that can be used to measure drought conditions. The duration, severity, and intensity are the three drought indication parameters proposed by Yevjevich (1967). Therefore, we set up a threshold for our study based on the literature on droughts definitions and behavior, specifically in the context of New Zealand. For example, Pourzand et al. (2020) in their study, used the NZDI to measure the frequency and severity of drought as two separate indicators. Timar and Apatov (2020) used soil moisture content and atmospheric moisture demand to compute potential evapotranspiration deficit (PED) as a drought intensity and duration measure. We used NZPGI to identify the drought conditions by defining two levels of a threshold by combining the index's frequency and severity. At the first level if the NZPGI ≤

30 for consecutively 10 or more days is identified as drought conditions. At the second level if the NZPGI ≤ 20 for consecutively 20 or more days is presumed as severe drought conditions. We accounted for the only summer season from December to March to compute drought conditions in New Zealand. We had a daily NZPGI dataset from 11,491 virtual climate station network (VCSN) (~5km) grid covering the whole of New Zealand.

Longitudinal Business Data (LBD)

LBD is the large microdata about New Zealand businesses collected through surveys/census by Stats New Zealand and Government agencies. The aforementioned Data is available on six major topics, including Agriculture, business financials, business practices, employment, innovation, and international trade and tourism. We combined Agriculture and business financial data sets for our study. The agricultural statistics were regularly collected by government agencies dated back to 1861. The data collected through agricultural production surveys or census starting from the year 2002 are not comparable to previous data collections due to selecting a sample of units rather than taking a complete enumeration were subject to sample errors. The average response rate of eligible units responding to Agriculture Production Surveys is 84% from 2002 to 2018. These respondents hold 87% of the estimated total agricultural output on average (StatsNZ, 2020). The business financial data is based on the IR10 financial statement summary form submitted to New Zealand Inland Revenue (IRD) for the processing of tax returns by businesses.

3.2 Sample construction and variables

Our sample population includes all businesses identified on Statistics New Zealand's Business Frame as having agricultural activity, specifically dairy farming and sheep/beef farming. We used agricultural industry ANZIC06/ANZIC96 codes to identify our sample population at the enterprise level from the Agricultural Production Survey/Census (APS/APC) in LBD from the year 2002 - 2018. We used the same APS/APC to identify each farm's geographical location at the meshblock level. Then we used the same enterprise number to link the sample population with financial tax data (IR10) in LBD. We used the financial tax data to compute the debt measures at each farm level.

For NZPGI, we had a dataset daily from 11,491 virtual climate station network (VCSN) (~5km) grid covering the whole of New Zealand. We assigned the unique location id to each VCSN. These VCSN locations are linked to meshblock based on the minimum distance between the two. The distances are measured based on the latitude and longitude of their centroid points. So, each farm location via their respective meshblock codes connected to its nearest grid station. This is how the farm financial data set got linked to NZPGI (See fig.5).

We used the following set of variables as debt and drought measures to address our research questions.

Table 2: Set of Variables description and purpose

Variables	**Description**	**Purpose**
Debt Measures (Dependent Variables)		
Real short-term debt	(Short-term debt / GDP deflator) x 100	To examine the short-term lending of farmers (1.1)
Real long-term debt	(Long-term debt / GDP deflator) x 100	To examine the long-term lending of farmers (1.2)
Real total debt	(Total debt / GDP deflator) x 100	To examine the total lending of farmers (1.3)
Debt-to-equity ratio	Total debt /total equity	To estimate the risk level to creditors. (1.4)
Debt coverage ratio	Net Income before interest and taxes/ (interest expense + short term debt)	To identify farms ability to pay off its short-term liabilities (1.5)
Drought Measures (Independent Variables)		
Drought	The NZPGI ≤ 30 for consecutively 10 or more days	To identify the drought conditions
Severe drought	The NZPGI ≤ 20 for consecutively 20 or more days	To identify the severe drought conditions
Consecutive drought season	The count of drought seasons at each farm level	To identify the continuous drought seasons each year

3.3 Empirical specification

Prior research has tested droughts' impacts using different methods like Kamber et al. (2013) used the VAR model to estimate drought shocks on macroeconomic variables. Kingwell and Xayavong (2017) used a linear quantile mixed model. We pursued an econometric approach to study the effects of drought on farm debts used by Pourzand et al. (2020). We used fixed-effect panel regression for dairy and non-dairy pasture farming for 2002-2018. Farm debt is our dependent variable, whereas NZPGI is our independent variable as a measure of drought conditions. The drought may last for more than one period; therefore, droughts could have lasting effects on farm debts and deal with it; we included lags on NZPGI of up to 2 years in our model.

A fixed-effects lag model (Hausman, Hall, & Griliches, 1984) for estimating the effects of droughts through NZPGI on the farm debts is:

$$\boldsymbol{Debt_{it} = \alpha + \delta_0 D_{it} + \delta_1 D_{i,t-1} + \delta_2 D_{i,t-2} + \delta_3 CD_{it} + c_i + u_{it}}$$

Where, $\boldsymbol{Debt_{it}}$ is the farm debt measures (real short-term debt, real long-term debt, real total debt, debt-to-equity ratio, and debt coverage ratio) of farm i at time t, $\boldsymbol{D_{it}}$ is the binary variable indicating drought conditions computed through NZPGI for farm i at time t. During the drought conditions, the value of $\boldsymbol{D}$ is assigned '1' if the NZPGI ≤ 30 for consecutively ten or more days, otherwise '0'. Similarly, for the severe drought conditions, the value of $\boldsymbol{D}$ is assigned '1' if the NZPGI ≤ 20 for consecutively 20 or more days, otherwise '0'. The $\boldsymbol{CD_{it}}$ is the measure of consecutive drought seasons, which is used as an additional drought measure in our model. The farm fixed effects $\boldsymbol{c_i}$ is an unobserved farm heterogeneity that may influence farm debts and may be correlated with current and past drought conditions $\boldsymbol{D}$ and $\boldsymbol{u_{it}}$ is idiosyncratic error represents unobserved factors that change over time and affect $\boldsymbol{Debt_{it}}$.

The financial data is converted to real dollar values by using the GDP implicit price deflator (source: Federal Reserve Economic Data) in New Zealand based on the index 2015 = 100.

4. Results

4.1 Drought Analysis

The New Zealand Pasture Growth Index frequency distribution is shown in figure 1 (appendix 1). The average value of the index lies between 40-60. The index had not reached its maximum value of 100 in our study period, indicating full growth of pasture. However, the minimum scale indicates reduced growth of pasture. The possible reason for low growth during the summer season can be an indication of drought. So, our focus remains on the values below 30 only as drought indicators at two levels.

Figure 2 (appendix 1) identifies the occurrence of drought at three levels over the years all over New Zealand. In the year 2013, the maximum of 81% of total grid stations of New Zealand indicates drought conditions and 12% as severe drought conditions. To review the district level's drought conditions, we combined the grid station data into district boundaries for each year. Figure 3 (appendix 1) identifies the top 10 New Zealand districts experiencing different levels of drought conditions. The southland district is the area hit by drought conditions most frequently from 1997 to 2018. The central Otago and Marlborough are hit by severe drought conditions the most from 1997 to 2018.

In figure 4 (appendix 1), we identified the number of districts that experienced drought conditions at more than 50 percent of their grid stations. In the years 2013 and 2015, most of the districts experienced drought conditions. We have seen the consistency of our results in the identification of drought conditions as well. The Hurunui district shows drought conditions at all its grid stations in the years 2015 and 2016.

4.2 Debt Measures Analysis

Table 3 describes the descriptive statistics of our dataset and main variables for dairy farming and sheep and beef farming.

Table 3: Descriptive Statistics

Variables	Dairy Farming			Sheep and Beef Farming		
	Observations	**Mean**	**Standard Deviation**	**Observations**	**Mean**	**Standard Deviation**
Real short-term-debt	26,142	403.23	1,324.02	27,690	111.43	503.86
Real long-term-debt	26,142	1,750.40	4,183.24	27,690	240.16	1,535.71
Real total debt	26,142	2,167.00	4,774.33	27,690	357.18	1,795.73
Debt-to-equity ratio	25,182	4.32	266.00	24,777	0.63	29.99
Coverage ratio	25,152	4.82	324.07	22,551	-4.96	565.11

Data Source: Statistics NZ

On average, dairy farming shows higher real short-term, long-term, and total debt than sheep and beef farming. Similarly, the debt-to-equity ratio is higher for dairy farming as compared to sheep and beef farming, which implies that dairy farming is highly leveraged. The higher average coverage ratio in dairy farming implies higher profitability for dairy farming.

We estimate our main equation for different debt measures include real short-term debt, real long-term debt, real total debt, debt to equity ratio, and coverage ratio at two different levels of droughts and specifications of regression models. In model (1) we didn't include the variable for consecutive drought seasons. In model (2) we tested our model only with the consecutive drought seasons. Whereas in a model (3) we used both time-lagged drought indicator and consecutive drought season. The estimation results for real debts as a dependent variable for dairy farming and, sheep and beef farming are shown in tables 4 and 5, respectively.

The regression results of the impacts of different drought conditions on real debt for dairy farming are shown in table 4. The results show a positive and significant impact of drought conditions on the real short term, long term, and total debt at the current time (t). The impact, in terms of magnitude and significance, gets stronger at the first lag (t-1) and second lag(t-2). Whereas during severe drought conditions, the impact is positive and significant at the current time (t) and second lag (t-2). The impact of consecutive drought seasons is significant and positive during droughts and severe droughts when tested alone and becomes insignificant when combined with drought conditions.

Table 4: Regression results for Debt of Dairy Farming (amount of debt in NZD in 000)

Indicators	Real Short-term-Debt			Real Long-term-Debt			Real Total Debt		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Droughts (NZPGI≤30 and consecutive days≥10)									
Drought (t)	33.00**		14.65	59.31**		63.25**	76.66**		60.36
	(16.67)		(26.57)	(27.73)		(31.54)	(34.59)		(42.12)
Drought (t-1)	50.28**		40.72*	67.02**		69.07**	106.54***		98.05**
	(20.14)		(23.40)	(31.49)		(32.76)	(39.06)		(42.33)
Drought (t-2)	86.31***		82.09***	133.91***		134.81***	213.36***		209.61***
	(15.61)		(16.63)	(42.11)		(42.84)	(43.10)		(44.25)
Cons. Drought Seasons		15.63**	9.16		13.29*	-1.96		26.98***	8.14
		(6.85)	(9.72)		(7.01)	(7.94)		(8.39)	(10.45)
Obs	26,142	26,142	26,142	26,142	26,142	26,142	26,142	26,142	26,142
Adj R-Sq	0.4341	0.4352	0.4342	0.7811	0.7809	0.7811	0.7911	0.7907	0.7911
Severe Droughts (NZPGI≤20 and consecutive days≥20)									
Drought (t)	59.03**		55.35	101.95*		209.29*	145.59**		244.85*
	(26.22)		(49.47)	(51.92)		(110.92)	(62.73)		(133.37)
Drought (t-1)	48.10*		47.23*	68.90		94.09	102.02		125.31
	(24.97)		(28.55)	(62.16)		(73.62)	(69.82)		(83.49)
Drought (t-2)	69.01**		68.83**	98.63		103.89	157.16**		162.03**
	(29.10)		(29.70)	(61.03)		(63.13)	(66.90)		(69.52)
Cons. Drought Seasons		38.12**	2.82		39.66	-82.38		68.80**	-76.18
		(15.17)	(26.31)		(25.78)	(54.01)		(30.72)	(63.60)
Obs	26,142	26,142	26,142	26,142	26,142	26,142	26,142	26,142	26,142
Adj R-Sq	0.4333	0.4332	0.4333	0.7809	0.7809	0.7809	0.7907	0.7906	0.7907

Note: * p<0.1, ** p<0.05, *** p<0.01 Robust standard errors clustered at farm level in parentheses Data Source: Statistics NZ

The regression results of the impacts of different drought conditions on real debt for sheep and beef farming are shown in table 5. The results show a positive and significant impact of drought and severe drought conditions on real short-term debt at the current time (t), first lag (t-1), and second lag(t-2). Whereas, we didn't find any significant impact of drought and severe drought conditions on long-term and total debt.

Table 5: Regression results for Debt of Sheep and Beef Farming

Indicators	Real Short-term-Debt			Real Long-term-Debt			Real Total Debt		
	(1)	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
Droughts (NZPGI≤30 and consecutive days≥10)									
Drought (t)	13.57***		6.04	2.15		-21.19	11.40*		-20.96
	(3.99)		(6.91)	(4.72)		(14.86)	(6.91)		(16.27)
Drought (t-1)	14.41***		10.57*	-0.43		-12.36	9.86		-6.68
	(5.52)		(5.63)	(5.88)		(9.15)	((8.37)		(10.94)
Drought (t-2)	15.40***		13.45**	-1.73		-7.78	10.05		1.66
	(5.71)		(5.91)	(5.88)		(6.69)	(8.66)		(9.39)
Cons. Drought		5.61***	3.80		8.18	11.79		13.41**	16.35**
Seasons		(1.88)	(2.55)		(5.19)	(7.35)		(5.25)	(7.41)
Obs	27,690	27,690	27,690	27,690	27,690	27,690	27,690	27,690	27,690
Adj R-Sq	0.5650	0.5649	0.5651	0.9034	0.9035	0.9035	0.8697	0.8698	0.8698
Severe Droughts (NZPGI≤20 and consecutive days≥20)									
Drought (t)	34.10**		5032***	-13.58		15.23	17.10		58.68**
	(16.89)		(17.61)	(17.85)		(23.39)	(19.80)		(25.16)
Drought (t-1)	25.34***		29.36***	-9.27		-1.71	12.00		22.92
	(8.03)		(8.49)	(19.10)		(19.89)	(20.82)		(21.82)
Drought (t-2)	26.52***		28.10***	-4.70		-1.72	16.91		21.21
	(8.13)		(8.23)	(19.95)		(20.21)	(18.62)		(18.94)
Cons. Drought		15.06*	-11.03*		-14.44	-20.74**		-1.23	-29.93***
Seasons		(8.60)	(6.49)		(10.65)	(10.19)		(10.92)	(10.83)

Obs	27,690	27,690	27,690	27,690	27,690	27,690	27,690	27,690	27,690
Adj R-Sq	0.5651	0.5647	0.5651	0.9034	0.9034	0.9034	0.8697	0.8697	0.8697

Note: * p<0.1, ** p<0.05, *** p<0.01 Robust standard errors clustered at farm level in parentheses Data Source: Statistics NZ

The estimation results for debt ratios as a dependent variable for dairy farming, and sheep and beef farming are shown in tables 6 and 7, respectively.

Table 6: Regression results for Debt Ratios of Dairy Farming

Indicators	Debt-to-equity ratio			Coverage ratio		
	(1)	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	-8.501**		-9.162**	-6.867		-4.797
	(4.220)		(4.234)	(5.699)		(4.054)
Drought (t-1)	4.374		4.028	5.474		6.567
	(5.114)		(5.716)	(5.650)		(6.663)
Drought (t-2)	5.701		5.547	4.174		4.655
	(6.847)		(6.856)	(5.467)		(5.909)
Cons. Drought Seasons		-0.33	0.329		-1.095	-1.036
		(0.67)	(0.814)		(0.920)	(1.112)
Obs	25,182	25,182	25,182	25,152	25,152	25,152
Adj R-Sq	0.0286	0.0283	0.0285	0.0083	0.0083	0.0083
Severe Droughts (NZPGI≤20 and consecutive days≥20)						
Drought (t)	-2.272		-7.329	1.113		2.476
	(4.481)		(9.207)	(1.556)		(2.916)
Drought (t-1)	-0.828		-2.027	-1.108		-0.791
	(3.580)		(4.673)	(1.247)		(1.273)
Drought (t-2)	-1.814		-2.065	-2.384*		-2.320*
	(3.450)		(3.668)	(1.229)		(1.203)
Cons. Drought Seasons		-0.214	3.881		0.151	-1.059
		(1.776)	(3.864)		(0.562)	(1.078)
Obs	25,182	25,182	25,182	25,152	25,152	25,152
Adj R-Sq	0.0283	0.0282	0.0283	0.0082	0.0082	0.0081

Note: * p<0.1, ** p<0.05, *** p<0.01   Robust standard errors clustered at farm level in parentheses   Data Source: Statistics NZ

Table 6 shows a negative and significant impact of drought conditions on the debt-to-equity ratio of dairy farmers. These results suggest two scenarios, either a reduction in debt as compared to equity or a more increase in equity than debt. To further evaluate these scenarios, we tested our same model with farmers' equity as shown in table 8. We found a positive and significant increase in equity for dairy farms. The magnitude of the increase in equity at lag t is higher than the total debt for dairy farmers. We may say that during the drought conditions, the dairy farmers start investing their equity to meet the environmental challenges. But after that, their reliance on external funding increases more than their equity investments.

We didn't find any significant impact of drought conditions on debt ratios for sheep and beef farming.

Table 7: Regression results for Debt Ratios of Sheep and Beef Farming

Indicators	Debt-to-equity ratio			Coverage ratio		
	(1)	(2)	(3)	(1)	(2)	(3)
Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	-0.343		0.037	-3.151		2.130
	(0.387)		(0.389)	(9.206)		(10.616)
Drought (t-1)	-0.118		0.078	0.160		20.883
	(0.381)		(0.401)	(7.108)		(8.030)
Drought (t-2)	0.580		0.680	-2.409		-1.032
	(0.423)		(0.434)	(8.139)		(8.120)
Cons. Drought Seasons		-0.160	-0.192*		-2.298	-2.686
		(0.107)	(0.110)		(2.381)	(2.818)
Obs	24,777	24,777	24,777	22,551	22,551	22,551
Adj R-Sq	0.0039	0.0039	0.0039	0.1053	0.1054	0.1053
Severe Droughts (NZPGI≤20 and consecutive days≥20)						
Drought (t)	-0.992		-1.209	8.800		6.061
	(1.368)		(1.828)	(10.538)		(12.964)

Drought (t-1)	1.458		1.400	-13.152		-13.919
	(0.950)		(0.874)	(30.512)		(33.314)
Drought (t-2)	-0.149		-0.172	15.357		15.037
	(1.443)		(1.490)	(12.195)		(12.069)
Cons. Drought Seasons		-0.215	0.156		3.635	1.962
		(0.474)	(0.399)		(4.875)	(8.591)
Obs	24,777	24,777	24,777	22,551	22,551	22,551
Adj R-Sq	0.0040	0.0039	0.0039	0.1053	0.1053	0.1053

Note: * p<0.1, ** p<0.05, *** p<0.01 Robust standard errors clustered at farm level in parentheses Data Source: Statistics NZ

Table 8: Regression results for equity

Indicators	**Dairy farming**			**Sheep and beef farming**		
	(1)	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	147.43***		114.03**	30.87		37.48
	(44.01)		(54.19)	(31.50)		(48.49)
Drought (t-1)	172.39**		154.99**	27.46		30.84
	(75.06)		(78.14)	(41.52)		(47.44)
Drought (t-2)	136.96***		129.28***	83.42**		85.14**
	(45.67)		(45.91)	(37.75)		(41.51)
Cons. Drought Seasons		42.22***	16.68		6.03	-3.34
		(13.39)	(17.28)		(8.49)	(13.01)
Obs	26,142	26,142	26,142	27,690	27,690	27,690
Adj R-Sq	0.8007	0.8007	0.8007	0.9010	0.9010	0.9010
Severe Droughts (NZPGI≤20 and consecutive days≥20)						
Drought (t)	174.22***		428.08***	-14.72		-67.07
	(62.49)		(116.90)	(35.60)		(54.32)
Drought (t-1)	69.45		129.03*	-24.99		-38.73
	(71.60)		(76.47)	(28.73)		(33.29)
Drought (t-2)	144.59**		157.03**	3.77		-1.65
	(69.89)		(70.62)	(27.32)		(27.34)
Cons. Drought Seasons		46.91	-195.83***		4.40	37.69
		(42.01)	(69.33)		(23.11)	(34.04)

Obs	26,142	26,142	26,142	27,690	27,690	27,690
Adj R-Sq	0.8005	0.8005	0.8005	0.9009	0.9009	0.9010

Note: * p<0.1, ** p<0.05, *** p<0.01 Robust standard errors clustered at farm level in parentheses Data Source: Statistics NZ

4.3 Robustness check

We used an alternative set of farm debt data reported by the Reserve Bank of New Zealand (RBNZ) of each bank for dairy and sheep/beef farming to run regressions and test whether our results are robust. We had quarterly dairy debt and sheep/beef debt data from the year 2009 to 2020 for each bank. We used the same thresholds of NZPGI to identify the drought conditions at dairy farmlands and sheep/beef farmlands respectively. To test our model rigorously we controlled for time-variant bank-specific variables. The regression results for both dairy and sheep/beef farming are summarized in table 9 in appendix I.

We found almost similar results to the prior findings, the coefficients in the robustness test model represents the amount of debt is in million New Zealand Dollars (NZD) consolidated at the bank level whereas in the original model the amount of debt is in thousands of New Zealand Dollars (NZD) consolidated at farm-level. Our results appear robust and provide a piece of evidence on the significant impact of drought conditions on farm debts of dairy and sheep/beef farming in New Zealand.

5. Conclusion

This paper empirically examined the impacts of droughts measured using NZPGI in New Zealand on the pasture reliant farm level debts. We used dairy, and sheep/beef farmers' financial data for seventeen years to identify if the farmers' borrowings or reliance on external funding sources increase during or after drought conditions. Our results show a statistically significant positive impact of droughts on short term and long-term debts of dairy farming and short term debt of sheep and beef farming. These results show the farm debts can be a possible link between drought and farm productivity/financial performance. That leads to further research in finding the impact of droughts on farms' productivity/financial performance that are more leveraged.

Our research shows the farmers' more reliance on the external source of funds during or after drought conditions, which can be a useful tool for the agriculture and financial sector in formulating policies for farmers' wellbeing and setting the cost of funds during or after drought conditions in the country.

Appendix 1

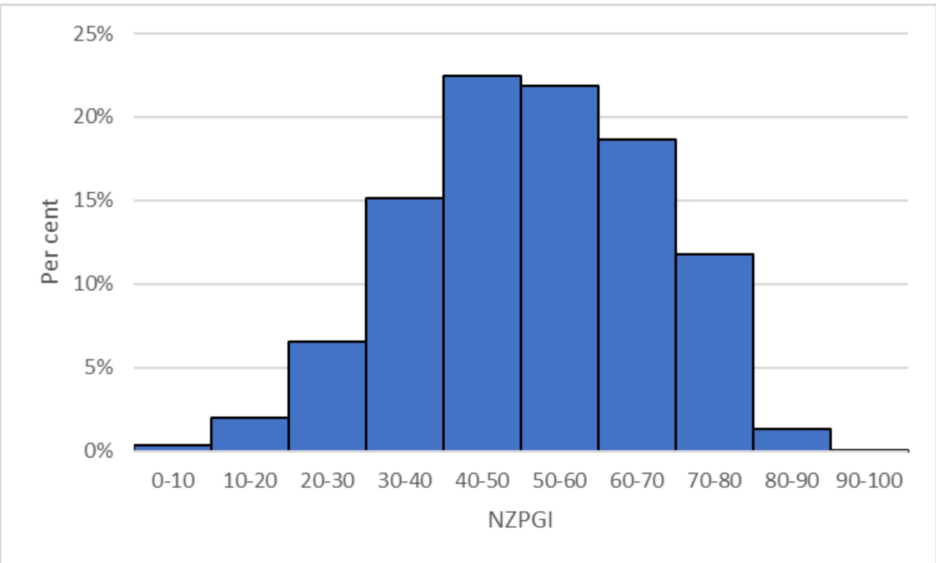

Figure 1: The frequency distribution of NZPGI

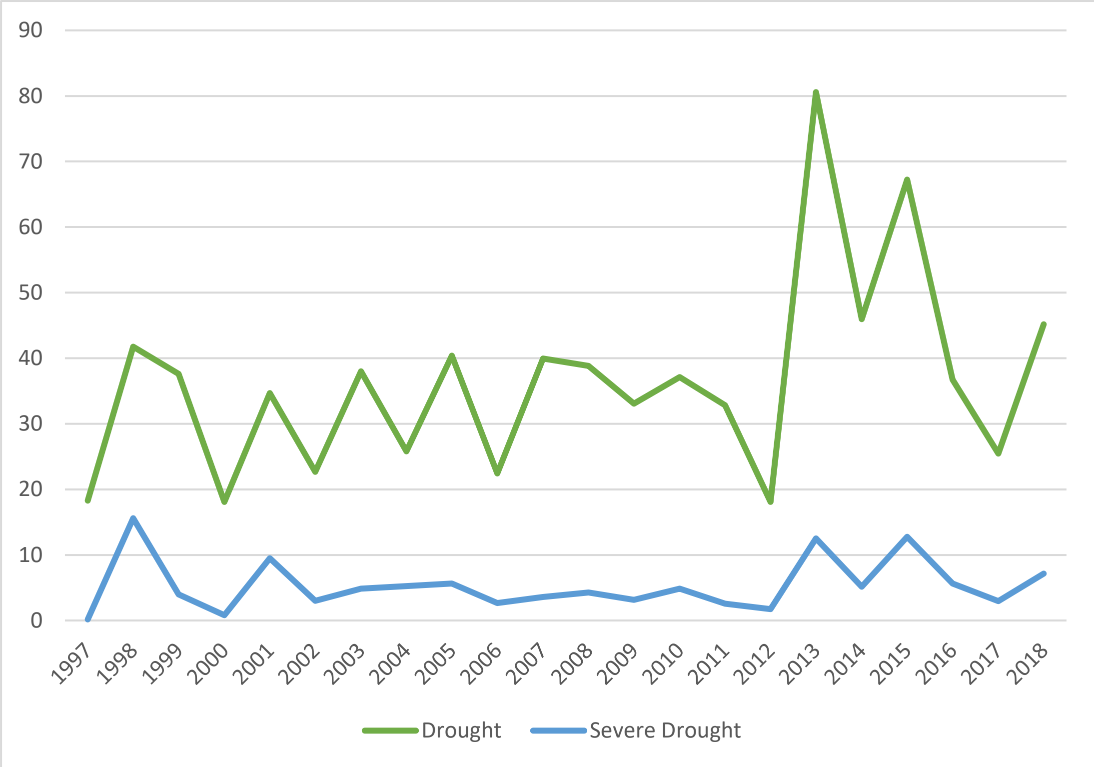

Figure 2:Identification of drought conditions at three levels over the years in New Zealand

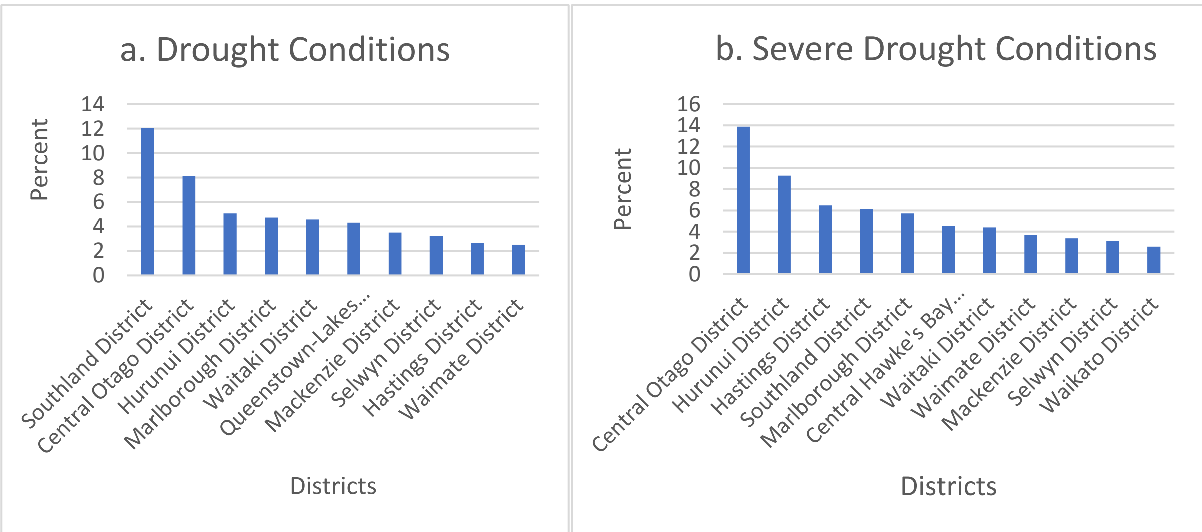

Figure 3: The top districts hit by different levels of drought conditions

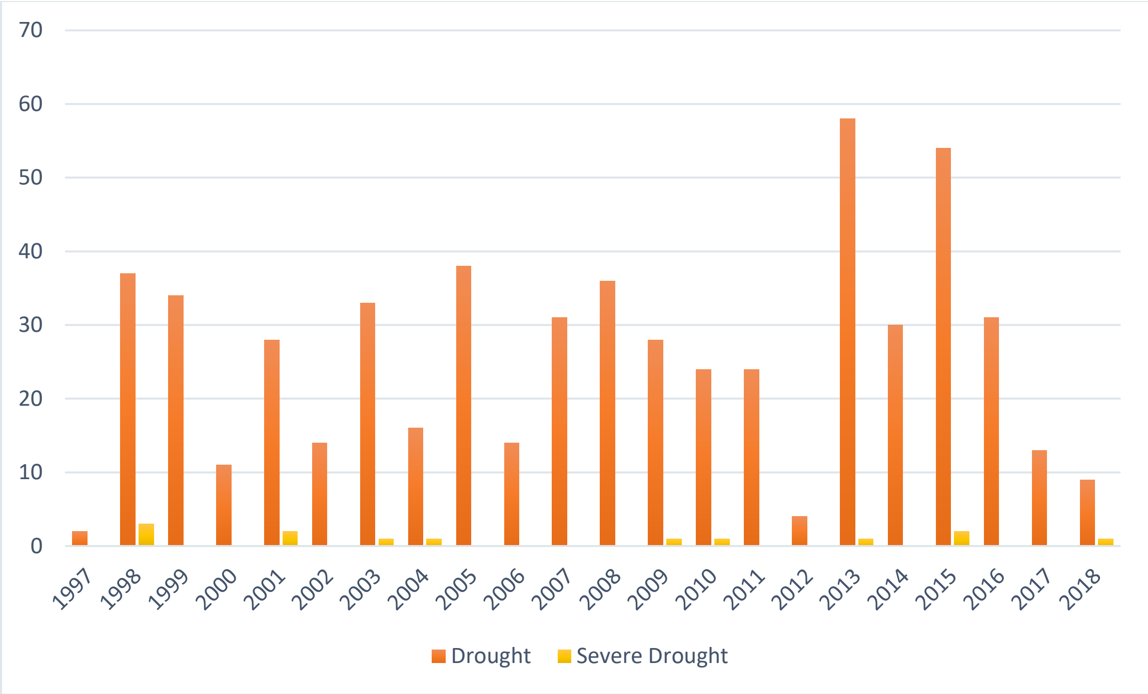

Figure 4:No. of Districts experiencing drought conditions at more than 50 percent of their grid stations

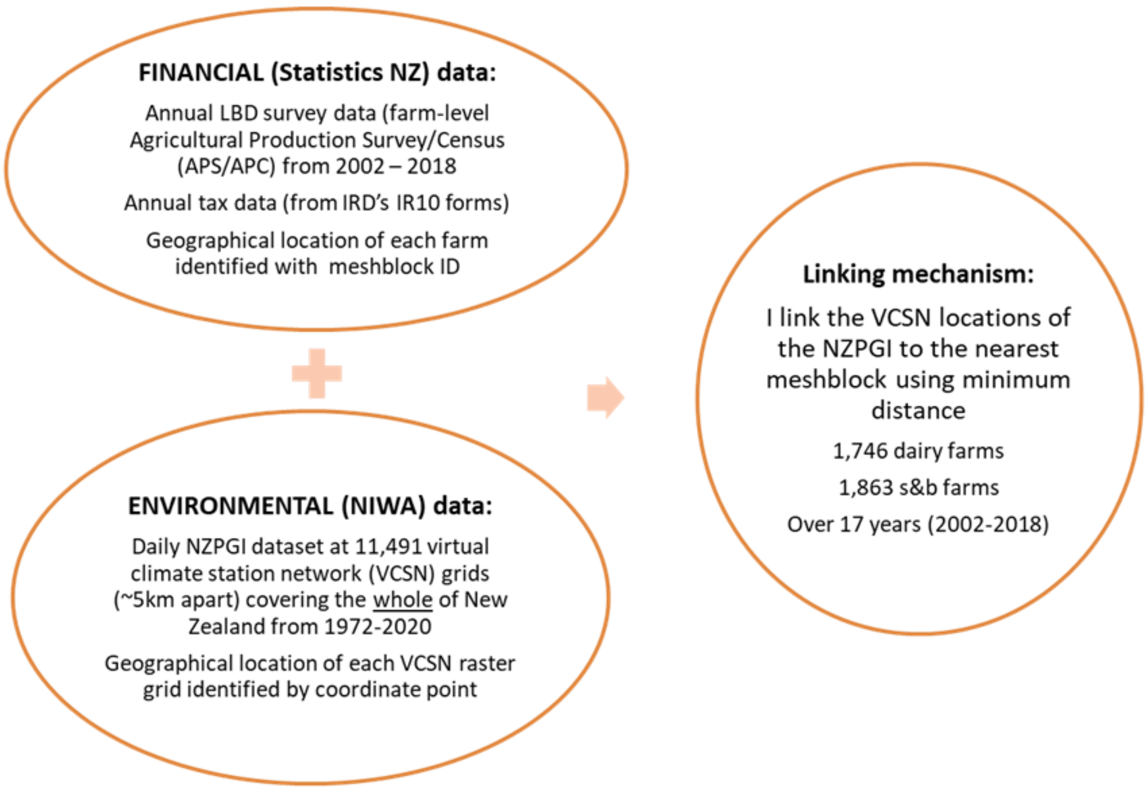

Figure 5. Sample construction and Linkage

Table 9: Regression results for total bank debt of dairy and sheep/beef farming

Indicators	(1)	(2)	(3)	(4)
Droughts (NZPGI≤30 and consecutive days≥10)				
	Dairy Farming		Sheep/Beef Farming	
Drought (t)	2.82* (1.37)	2.93** (1.29)	0.71** (0.28)	0.82*** (0.24)
Drought (t-1)	4.36* (2.01)	4.46** (1.96)	0.95** (0.30)	1.10*** (0.28)
Drought (t-2)	1.99 (1.21)	2.06* (1.22)	0.09 (0.35)	0.13 (0.38)
Bank Size	220.76 (125.73)	286.61*** (45.64)	-67.52 (46.65)	22.38 (18.13)
Bank Performance (ROE)	-0.02 (6.90)	0.46 (6.89)	-2.55 (2.26)	-1.72 (1.48)
Bank Solvency (Capital Ratio)	102.85 (117.83)	104.37 (118.76)	44.93 (42.19)	47.84 (43.98)
Bank Efficiency (Op Income- Op Exp Ratio)	322.48 (328.51)	361.57 (333.86)	120.75 (89.46)	156.01 (104.04)
Methods	FE	RE	FE	RE
Obs	389	389	366	366
n	9	9	9	9
t	48	48	48	48
Adj R-sq	0.9469	0.9469	0.9301	0.9301
Severe Droughts (NZPGI≤20 and consecutive days≥20)				
	Dairy Farming		Sheep/Beef Farming	
Drought (t)	17.85* (8.30)	18.29** (7.86)	10.07*** (2.81)	10.76*** (2.65)
Drought (t-1)	20.67* (10.07)	21.13** (9.66)	11.10*** (3.03)	11.89*** (3.01)
Drought (t-2)	18.26* (8.85)	18.72** (8.77)	6.24** (2.25)	6.71*** (2.15)
Bank Size	229.34 (125.42)	289.17*** (46.21)	-62.16 (42.49)	20.53 (17.05)
Bank Performance (ROE)	2.06 (6.72)	2.52 (6.60)	-1.77 (2.18)	-0.96 (1.39)
Bank Solvency (Capital Ratio)	96.23 (114.55)	97.43 (115.40)	43.57 (41.15)	46.13 (42.74)
Bank Efficiency (Op Income- Op Exp Ratio)	339.61 (327.24)	376.80 (332.71)	129.27 (86.95)	161.78 (100.39)
Methods	FE	RE	FE	RE
Obs	389	389	368	366
n	9	9	9	9
t	48	48	48	48
Adj R-sq	0.9479	0.9479	0.933	0.933

Note:
* p<0.1, ** p<0.05, *** p<0.01 Robust standard errors in parentheses Data Source: RBNZ & NIWA

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