IMPACT OF DROUGHTS ON FINANCIAL MARKETS AND THE ECONOMY: EVIDENCE FROM DAIRY, SHEEP AND BEEF FARMING

BY

SHABANA KAMAL

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In the name of ALLAH, the most merciful and benevolent

I dedicate my dissertation to

Muhammad Mansoor ul Haq

my sole and dearly loved brother, who tragically lost his life to COVID-19 while I was pursuing my PhD

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Disclaimer

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Abstract

Three manuscripts form the foundation of this dissertation exploring the impact of droughts on financial markets and the economy focusing on dairy, sheep and beef farming. The first manuscript exhibited in chapter 2 advances the knowledge by empirically examining the relationships between droughts and farms' capital structure (measured in terms of real debt and equity) in New Zealand. Using microeconomic farm-level financial information accessible from the tax authorities, we evaluate how past droughts (measured by the New Zealand Pasture Growth Index) impact farms' capital structure. We demonstrate that impact of droughts on short-term and long-term debts, equity for dairy farms, and short-term debt for sheep and beef farms is positive and statistically significant.

The second manuscript described in chapter 3 empirically tests the relationships between droughts (as measured by the New Zealand Pasture Growth Index-NZPGI) and banks' agricultural non-performing loans (NPLs) (loans overdue by 90 days or more) at the regional level. This estimation pools data from the National Institute of Water and Atmospheric Research Ltd (NIWA), the Reserve Bank of New Zealand (RBNZ), and Federated Farmers' farming surveys and tests the model using panel data fixed-effects regression modelling. Our results illustrate a statistically significant positive impact of droughts on dairy farming NPLs. However, we find no significant impact of droughts on sheep/beef farming NPLs.

The third manuscript stated in chapter 4 outlines the impact of droughts on dairy, sheep, and beef sector exports – measured in terms of both volume and value. This study produces estimates at the world, and income level, based on data from UN Comtrade, the World Bank, and a measure of droughts (the Standardized Precipitation Evapotranspiration Index) of regularly exporting countries from 1995-2020. Findings suggest that droughts over the studied time significantly affected agricultural export quantities of dairy, sheep, and beef. We find that while high-income nations exhibit a greater decline in the export of beef and sheep both during

and after droughts, medium-low-income countries show a greater reduction in the export of dairy products during droughts. We also find that the influence of droughts on export values is positive for the dairy sector while it is negative for the sheep sector.

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Chapter 1: **Introduction**

Climate change can increase the intensity and frequency of future droughts and leads to significant effects on the national and global economy. Drought risks are projected to increase from 3% to 8% over the 21st century in many regions, and a significant risk of agricultural drought is also projected to increase by 100–250% at 4°C global warming in southwestern North America, southwest Africa, southern Asia and Australia (Caretta & R. Morgan, 2022). There is a dearth of research on the economic and financial impacts of droughts. For example, do droughts change the balance sheets of businesses by changing their capital structure? Can droughts bring this physical risk into the banking sector? Can droughts have an impact on trade? This dissertation advances a quantitative understanding of the potential impacts and implications of droughts on New Zealand's financial system and globally through their impact on farms' capital structure, agriculture sector debt exposures in banks' balance sheets and agriculture exports.

Droughts are categorised into different types, such as meteorological, hydrological and agricultural droughts. These types of droughts are linked in terms of the processes that cause them, as meteorological droughts (persistent low precipitation) propagate hydrological droughts (reduction in the water supply) which in turn can lead to agricultural droughts (increases plant water stress) (Douville et al., 2021). Seneviratne (2021) found that increasing agricultural drought trends are more evident than increasing trends in meteorological drought in several regions due to increased evaporative demand. These droughts can cause substantial economic damage through crop damage and decreases in yields.

Drought-related events contributed to 7% of all disasters between 1970 and 2019 (WMO, 2021). Drought risk measured in terms of hazard, vulnerability and exposure is higher for populated areas and intensive crops and livestock farming regions, such as southern and central Asia, south-eastern South America, central Europe and the south-eastern USA (Caretta & R.

Morgan, 2022; Hagenlocher et al., 2019). Formetta and Feyen (2019) show economic vulnerability to drought was twice as high in lower-income countries compared to higher-income countries during 2007–2016.

Major drought events worldwide have had substantial societal and ecological impacts, including reduced crop yields, shortages of drinking water, wildfires causing deaths of people and animals, impacting the habitats of threatened species, and widespread economic losses. In addition, long-term drought trends are clearer for agricultural droughts compared to meteorological droughts (Douville et al., 2021; Seneviratne et al., 2021). Most studies focus on meteorological (precipitation) drought, and sometimes also consider temperature anomalies. However, a complete examination of droughts' economic impacts often requires consideration of hydrological and agricultural drought.

Agriculture production has been impacted by changes in the hydrological cycle. Between 1983 and 2009, approximately 454 million hectares of the global harvested areas experienced yield losses induced by meteorological drought, with the cumulative production losses resulting in USD166 billion (Kim, Iizumi, & Nishimori, 2019). Globally, between 1961 and 2006, it has been estimated that 25% yield loss occurred, with yield loss probability increasing by 22% for maize, 9% for rice and 22% for soybean under drought conditions (Leng & Hall, 2019). Livestock production has also been affected by the increasing frequency of drought (Godde et al., 2019). Droughts in a country like New Zealand, which is heavily dependent on agricultural exports, can severely affect the economy. Estimates suggest that the 2008 drought cost the national economy over $US 1.5 billion (Butcher & Ford, 2009), and the 2013 drought lowered annual GDP by 0.6 per cent (Kamber, McDonald, & Price, 2013). In summary, the severity of drought events in many parts of the world causes reduced agricultural yields and loss of billions of dollars.

The total farm debt in New Zealand is NZ$ 62.3 Billion, which has increased by 270 per cent over the past twenty years and recently accounted for 14 per cent of total bank lending (RBNZ, 2021a). There is a serious concern about the rapid growth of farm lending, in particular to the dairy sector, and the Reserve Bank of New Zealand (RBNZ) views this indebtedness as the financial system's main domestic vulnerability (RBNZ, 2021b). The financial fragility of farms' balance sheets can also slow down debt recoveries. A recent economic survey report by Dairy NZ, observed an increase of 69% in term liabilities from NZD 2.4 million per farm to NZD 4.1 million per farm over the last ten years, whereas farm size has increased by only 17%. This debt has also become more concentrated that a current debtor would have to have multiple seasons of great weather, good dairy pay-outs, and an increase in land prices to reach financial resilience (i.e. with loan-to-value ratios below ~80%) (DairyNZ, 2018).

Yet, despite the importance of this risk to the future sustainability of NZ's national economy, this risk is largely unquantified. Despite two costly droughts (> NZD 1 billion) in the last 10 years, New Zealand's major banks and the RBNZ have yet to incorporate climate modelling in the stress testing of their portfolios. There is a clear and present need to understand the links between these key causal chains and extend existing research efforts in this important direction. While keeping in mind the current and projected risks associated with droughts, this dissertation focuses on quantifying some of the impacts of the drought at a national and global level. We quantify the economic effect of drought in the following ways: (i) on individual farms' capital structure i.e., debt and equity (in the second chapter); (ii) on banks' balance sheets through Non-Performing Loans (NPLs) portfolios (in the third chapter); and (iii) on dairy exports globally (in the fourth chapter).

Therefore, the second chapter of this dissertation extends the literature by empirically testing the relationships between droughts and farms' capital structure (measured in terms of real debt and equity) in New Zealand. This chapter employs micro-econometric modelling to quantify how past droughts (as measured by the latest and improved version of the New Zealand Pasture Growth Index (NZPGI) impact farms' capital structure. Data from the National Institute of Water and Atmospheric Research Ltd (NIWA) and Statistics New Zealand Longitudinal Business Database (LBD) are used to estimate our model.

Weather shocks can adversely affect farm income which in turn can lead to deteriorating farm balance sheets, increasing liabilities, and ultimately debt defaults. The link between weather risk and debt defaults is as yet unquantified in the NZ context. Therefore, the third chapter empirically tests the relationships between droughts (as measured by the NZPGI) and banks' agricultural non-performing loans (NPLs) (loans overdue by 90 days or more) at the regional level. Using panel data fixed-effects regression modelling, this estimation combines weather and financial data from NIWA, the RBNZ, and Federated Farmers' farming surveys. We then evaluate the implications of these findings for policymakers and the banking sector.

Droughts have the potential to affect an entire economy, specifically the agriculture sector as it contributes to the export sector. In the fourth chapter, we investigate the impact of droughts on dairy, sheep, and beef sector exports – measured in terms of both volume and value. The study produces estimates of these impacts on exports using data from the UN Comtrade, the World Bank, and a measure of droughts (the Standardized Precipitation Evapotranspiration Index) of exporting countries from 1995-2020.

1.1 References

Butcher, G., & Ford, S. (2009). *Modeling the regional economic impacts of the 2007/08 drought: results and lessons*. Retrieved from https://www.rbnz.govt.nz/research-and-publications/analytical-notes/2013/an2013-02

Caretta, M. A., A. Mukherji, M. Arfanuzzaman, R.A. Betts, A. Gelfan, Y. Hirabayashi, T.K. Lissner, J. Liu, E. Lopez Gunn,, & R. Morgan, S. M., and S. Supratid,. (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In D. C. R. H.-O. Pörtner, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, & A. O. V. Möller, B. Rama, (Eds.), *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 551–712). Cambridge, UK and New York, NY, USA,: Cambridge University Press.

DairyNZ. (2018). *DairyNZ Economic Survey 2017-18*. Retrieved from https://www.dairynz.co.nz/publications/dairy-industry/dairynz-economic-survey-2017-18/

Douville, H., Raghavan, K., Renwick, J., Allan, R. P., Arias, P. A., Barlow, M., . . . Zolina, O. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to 45 the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonno, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (Eds.), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to 45 the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1055-1210): Cambridge University Press.

Formetta, G., & Feyen, L. (2019). Empirical evidence of declining global vulnerability to climate-related hazards. *Global Environmental Change, 57*, 101920.

Godde, C., Dizyee, K., Ash, A., Thornton, P., Sloat, L., Roura, E., . . . Herrero, M. (2019). Climate change and variability impacts on grazing herds: Insights from a system dynamics approach for semi-arid Australian rangelands. *Global change biology, 25*(9), 3091-3109. doi:10.1111/gcb.14669

Hagenlocher, M., Meza, I., Anderson, C. C., Min, A., Renaud, F. G., Walz, Y., . . . Sebesvari, Z. (2019). Drought vulnerability and risk assessments: state of the art, persistent gaps, and research agenda. *Environmental Research Letters, 14*(8), 083002. doi:10.1088/1748-9326/ab225d

Kamber, G., McDonald, C., & Price, G. (2013). *Drying out: Investigating the economic effects of drought in New Zealand*. Retrieved from https://www.rbnz.govt.nz/research-and-publications/analytical-notes/2013/an2013-02

Kim, W., Iizumi, T., & Nishimori, M. (2019). Global patterns of crop production losses associated with droughts from 1983 to 2009. *Journal of Applied Meteorology and Climatology, 58*(6), 1233-1244. doi:doi:10.1175/JAMC-D-18-0174.1

Leng, G., & Hall, J. (2019). Crop yield sensitivity of global major agricultural countries to droughts and the projected changes in the future. *Science of the Total Environment, 654*, 811-821. doi:10.1016/j.scitotenv.2018.10.434

Reserve Bank of New Zealand. (2021a). Banks: Assets – Loans by purpose (S31). Retrieved from https://www.rbnz.govt.nz/statistics/s31-banks-assets-loans-by-purpose

Reserve Bank of New Zealand. (2021b). *Financial Stability Report May 2021*. Retrieved from https://www.rbnz.govt.nz/financial-stability/financial-stability-report

Seneviratne, S. I., X. Zhang, M. Adnan, W. Badi, C. Dereczynski, A. Di Luca, S. Ghosh, I. Iskandar, J. Kossin, S. Lewis, F. Otto, I. Pinto, M. Satoh, S.M. Vicente-Serrano, M. Wehner, and B. Zhou,. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to 45 the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonno, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (Eds.), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to 45 the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1513–1766): Cambridge University Press.

World Meteorological Organization (WMO). (2021). *WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019)*. Retrieved from https://library.wmo.int/index.php?lvl=notice_display&id=21930#.Ywg1xnZByUm

Chapter 2: **Impact of droughts on farms' capital structure: Empirical evidence from New Zealand**

Abstract

The interaction between climate change, agriculture, and financial markets is a topic that has been researched relatively little thus far. This chapter intends to extend the literature by empirically testing the relationships between droughts and farms' capital structure (measured in terms of real debt and equity) in New Zealand. Using microeconomic farm-level financial records available from the tax authorities, we quantify how past droughts (measured by the New Zealand Pasture Growth Index) impact farms' capital structure. We show a statistically significant positive impact of droughts on short-term, long-term debts, and equity for dairy farms, and on short-term debt for sheep and beef farms.

2.1 Introduction

In the age of anthropogenic climate change, countries increasingly focus on drought risks. In Aotearoa New Zealand, successive projections by the National Institute of Water and Atmospheric (NIWA) suggest that climate change will lead to more frequent and intense droughts in most of the main agricultural areas (NIWA, 2017). Past data reveal that about 85 per cent of New Zealand districts were affected by droughts during the period 2007-2016. Droughts in a country like New Zealand, which is heavily dependent on agricultural exports, can severely affect the economy. Estimates suggest that the 2008 drought cost the national economy over $US 1.5 billion (Butcher & Ford, 2009), and the 2013 drought lowered annual GDP by 0.6 per cent (Kamber, McDonald, & Price, 2013).

Droughts can generally lead to a reduction in agriculture production, mainly in pasture-based animal husbandry and un-irrigated crop production. See, for example, evidence from Australia (Edwards, Gray, & Hunter, 2009; Tran, Stoeckl, Esparon, & Jarvis, 2016) and New Zealand (Timar & Apatov, 2020). But, droughts may also lead to higher farm revenue if prices go up as a consequence of the drought (Kingwell & Xayavong, 2017; Pourzand, Noy, & Sağlam, 2020), though Pourzand et al. (2020) also record an increase in debts as costs go up as well. Debts can help to smooth income between financially good and difficult years (Greig, Nuthall, & Old, 2019; Ma, Renwick, & Zhou, 2020). Statistics from the Reserve Bank of New Zealand reveal that the total farm debt has increased by 270 per cent over the past twenty years (RBNZ, 2019).

When farmers face the need to obtain additional funding, they may either borrow externally (debt) or use their resources (equity) to finance both desired consumption smoothing or necessary investments. The use of farm debt or personal equity may be an important factor during droughts. While previous research studies have explored the linkage between droughts and agricultural productivity and performance, they leave an important research question largely unanswered: *Is there an association between droughts with farm capital structure (the choice between debt or equity)?*

This study attempts to answer the aforementioned question in Aotearoa New Zealand’s (NZ) context by exploring the empirical relationship between droughts and farm debts and equity, using NIWA data on droughts and Statistics NZ's Longitudinal Business Database (LBD) on farms’ balance sheets. The LBD contains the financial records of all farms in NZ as these have been submitted to the tax authorities. Focusing on dairy, sheep and beef farms, we argue that during or after experiencing drought conditions, farmers may face financial difficulties due to the low growth of pasture. They will then need to spend more money on animal feed or increase their pasture production capacity. The need to fund this change can be met using internal (equity) or external (debt) sources of funds. This need can be different across dairy farms and sheep/beef farms due to their different operational processes. Dairy cows must remain healthy and alive to produce milk during or after drought seasons. In contrast, sheep/beef farms during drought seasons can be slaughtered to produce meat. This can solve the short-term liquidity crunch those farmers may be facing but can impose added longer-term challenges.

Furthermore, the sensitivity of the stock to changes in pasture conditions may be different across different types of animals. Dairy cows are considered long-term assets for dairy farms, while the animal stock for sheep/beef farms is handled as current assets in their financial records. Therefore, longer-term de-stocking challenges can be acute for dairy farms as compared to sheep/beef farms. Dairy farms can replenish their animal stock (long-term assets) through long-term financing options, while sheep/beef farms most likely require short-term financing options to replenish their animal stock in the working capital cycle.

The rest of the chapter is organized as follows: We first detail some of the relevant insights from the existing literature and place this study's contribution within the existing body of knowledge. Sections 2.3, 2.4 and 2.5 describes drought measures and concepts, the New

Zealand context and our data and the models we estimate respectively. The main results and robustness check are summarized in section 2.6, followed by section 2.7 which concludes with thoughts about areas for future research.

2.2 Literature on farm balance sheets and natural hazards

Literature is scarce on the financial impact of droughts. However, some recent research has provided empirical evidence on the economic costs of droughts. For example, Huynh, Nguyen, and Truong (2020) report a significant positive correlation between drought risk and the cost of equity capital. The private debt market is also reportedly affected by droughts. Do, Nguyen, Truong, and Vu (2021) show banks charge higher loan spreads for drought-affected borrowers. Previously, Lesk, Rowhani, and Ramankutty (2016) studied the global-scale impact of droughts on crop production and found that droughts damage national crop production.

Prior research testing the impact of droughts on agricultural businesses 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 affected the business indicators they examined (business equity, operating profit/ha, return on capital, and the debt-to-income ratio), also for Australian farms. 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 negative impact of droughts on dairy farms' gross output and net profit. They also recorded an unexpected reduction in intermediate expenditures of dairy farms in New Zealand against an increase in drought intensity.

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 a drought in New Zealand.

Elsewhere, Kuwayama, Thompson, Bernknopf, Zaitchik, and Vail (2019) used the U.S. Drought Monitor index, crop yields, and farm income data during the 2001–2013 time period to measure the effect of droughts on farms. They found negative and statistically significant effects for each additional week of drought in dryland counties on corn and soybean yields but negligible to no effect on measures of farm income. Similarly, in Europe, Naumann, Cammalleri, Mentaschi, and Feyen (2021) estimated more than 50% of total agricultural losses from adverse events can be attributed to droughts in Europe and 60% in the Mediterranean region.

Recent evidence from high-income countries has focused on the association between farm debts and farm performance (irrespective of weather shocks). For example, Ma et al. (2020) show that a higher debt ratio significantly decreases both the technical efficiency of dairy farms and their return on assets in New Zealand. They reveal the time-specific effects: A high debt ratio increased dairy productivity between 2005 and 2009, while it is associated with decreased dairy productivity between 2011 and 2014. Earlier and differing results were reported by Mugera and Nyambane (2015) for short-term and long-term debt effects on farm technical efficiency using evidence from farms in Western Australia. They found a positive association between farm technical efficiency and short-term debt, tax liability, and capital investment, but a negative association with off-farm income-generating activities. They did not find an effect of long-term debt on production efficiency and returns on assets.

The profitability of highly leveraged farms can be impacted during droughts. The evidence is supported in recent studies by Ma et al. (2020) and Godfrey et al. (2021). The findings from Ma et al. (2020) show that farm debt is significantly and negatively associated with both dairy productivity and profitability. Godfrey et al. (2021) used copula and Monte Carlo simulation techniques to estimate the financial and business risks faced by a typical wool and meat lamb enterprise in South-Eastern Australia. Their estimation results identify reduced profitability for farms with higher debt accumulation due to drought shocks.

Moreover, in the recent study of Pourzand et al. (2020) on farms' business indicators - income and profitability, they investigate debt-to-income ratio and interest coverage ratio. Our study is different in focusing on the financing choices of farms; i.e., how farm businesses obtain funding (debt or equity). The ratio analysis, as done by Pourzand et al. (2020) is more difficult to interpret, as both the denominator and the numerator may change concurrently. We examined the determinants of the amount of debt (short term, long term and total debt) and equity, either required for operational or working capital or to acquire fixed assets like land, equipment, and machinery.

There is limited empirical evidence on the sensitivity of the capital structure of farms (their allocation of liability between debt and equity) to any change brought about during or after droughts. We attempt to pursue this line of inquiry by proposing and empirically testing the impact of droughts (as measured by the latest and improved version of the New Zealand Pasture Growth Index-NZPGI) on-farm debt and equity.

Our decision to focus on the NZPGI follows from Pourzand et al. (2020) on some of the counter-intuitive results (as discussed earlier) they found while utilizing the New Zealand Drought Index (NZDI) to examine the impact of droughts on farm income and profit; see Table ***2.6*** (in section 2.9.2 Appendix – Tables) for comparison of various drought indices. They argued that the NZDI may not be designed to capture the true impact of drought on-farm operations and as such, may not account for 'agricultural drought.' By focusing on an index that was designed to measure pasture growth, we can turn out attention to the exact mechanism through which droughts are likely to have an impact on dairy, sheep and beef farms – through their impact on the availability of nutritious pasture.

In the following section, we discuss the current state of drought research, the various drought measures proposed and tested in the literature, how the measure of drought we are using, the NZPGI, differs from others, and how our measure is well suited to the New Zealand context.

2.3 Drought measures and concepts

It remains difficult to adequately define, identify, and measure droughts due to their complex nature. Droughts are typically considered on five different dimensions: metrological, soil moisture, hydrological, socioeconomic, and environmental (OECD, 2016). All these interlinked dimensions define droughts as conditions associated with less rainfall, low levels of soil moisture, and modified water cycles (possibly due to human activities).

Agricultural droughts, a subset of the socioeconomic phenomenon, were defined by the American Meteorological Society as: "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) define a drought index as “a prime variable for assessing the effect of the drought and defining different drought parameters, like intensity, duration, severity, and spatial extent for different time scales. The monthly time scale seems to be more appropriate for monitoring the effects of a drought in situations related to agriculture". Bernknopf et al. (2018) present a better understanding of drought by using satellite missions to measure groundwater storage and soil moisture for drought monitoring. Accordingly, several different drought indices were developed in the past several decades, whose aim is typically to quantify some aspect of a drought. Table ***2.6*** (in section 2.9.2 Appendix – Tables) summarizes some of these indices. Our preferred indicator is the New Zealand Pasture Growth Index (NZPGI) which is calculated at grid-cell level (5x5km), which allows us to accurately connect it to farms' locations. The NZ Ministry for the Environment has already identified drought as one of the major constraints to pasture grazing in New Zealand (MfE, 2001), and our study focuses on dairy and, sheep and beef farming. These are heavily reliant on pastures, and much of that pasture is not irrigated and therefore more vulnerable to droughts. These sectors are by far the two most important sectors in NZ's agricultural production.

The NZPGI measures pasture grass growth based on radiative energy, soil moisture, and temperature potential for New Zealand's dairy regions, using data from the National Climate Station Network (NCSN). It was originally developed for use by New Zealand investors in agriculture, and supported by the New Zealand Stock Exchange (NZX, 2019). There are two versions of the NZPGI, both developed by NIWA. The original version of the NZPGI was based on a pasture growth modelling developed in Australia. The new version of the NZPGI was improved by empirical calibration using past pasture growth data and the history of the NZPGI (Stone, Carey-Smith, Dean, Harrington, & Storey, 2019). The original version of the NZPGI assigned equal weights on measuring factors (radiative energy, soil moisture, and temperature), whereas the revised version re-weighted these factors. Moreover, the new version is adjusted to match the units of pasture growth, of kg of dry matter per hectare per day, thus discarding the 0-to-1 index range in the older version.

The values of the NZPGI correspond to the amount of grass expected to grow in a "normal" hectare of farmland. The lower values indicate less grass growth, and the upper values indicate ideal conditions or more growth of grass. The values show a unit of kg of dry matter per hectare per day.

Other vegetation growth measures have provided insights into agricultural drought severity elsewhere. For example, Weier and Herring (2000) and NASA (2000) used the Normalized Difference Vegetation Index (NDVI), obtained from remote sensing (satellite) data, which considers reduced plant growth, as a drought indicator. Similarly, the NDVI was used to estimate the regional pasture growth rate (PGR) in the agricultural zone of Western Australia (Hill, Donald, Hyder, & Smith, 2004).

2.4 The New Zealand context

2.4.1 THE AGRICULTURE SECTOR IN NEW ZEALAND

Agriculture is an important sector in the New Zealand economy. The sector contributes 4 per cent to its Gross Domestic Product worth more than NZ$12 billion in 2019 (StatsNZ, 2021) Dairy farming is by far the largest agricultural sub-sector, followed by beef and sheep farming and horticulture (NZ Govt., 2016). Agriculture, and especially dairy, is the biggest contributor to trade, constituting about 34 per cent of New Zealand's exports worth NZ$19.7 billion, which directly added NZ$10.2 billion to the economy. In 30 years, dairy exports have grown ten times from NZ$2 billion to almost $20 billion per year. The sheep and beef sector is delivering about NZ$8.3 billion in New Zealand's export revenue and directly adding around NZ$5.8 billion to the economy (Dorigo & Ballingall, 2020).

2.4.2 DROUGHT RISKS IN NEW ZEALAND

NIWA defines droughts as a deficit in rainfall, restricting human activities like farming (NIWA, 2019). The Ministry for Prime Industries (MPI) of New Zealand classifies droughts into three main adverse events: localized, medium-scale, and large-scale, based on the spatial extent and the intensity of an event and the ability to prepare and the capacity to cope with it. New Zealand's most intensive drought was in 2013. This event affected some parts of the South Island and the whole of the North Island.

New Zealand has been experiencing a change in regional rainfall patterns over the past fifty years; these are changes associated with anthropogenic climate change. A Ministry for Environment and Statistics New Zealand report from 2017 found dryer soils at seven sites out of a total of thirty sites from 1972 to 2016. Many of the most drought-prone regions are expected to see further changes in rainfall patterns and rising temperatures that will cause even more droughts (MfE and StatsNZ, 2017). The western part of the country is predicted to experience increased rainfall during spring and winter, whereas the east and north are expected to experience decreasing trends. 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 the Southern Alps have been melting and reducing the volume of ice at a rate of 11% over the period 1976 to 2005 (NIWA, 2007b). This is also affecting the flow of water in rivers during spring and summer which have a significant consequence for irrigated farmland, especially in Canterbury.

New Zealand's most extreme recent drought was in 2013. Northland, the region at the northern end of the North Island, is the most frequently drought-affected region with four drought events affecting it from 2007 to 2017 (A. Mol, A. Tait, & G. Macara, 2017). The eastern part of the Hurunui district (South Island) experienced the longest drought in recent times, during 2015-2016 (A. Mol et al., 2017). Regional climate modelling projects an increased drought severity in most parts of the country except for the West Coast and Southland (in the South Island), and Taranaki-Manawatu (North Island) (MfE, 2018).

2.4.3 AGRICULTURAL DEBT TRENDS IN NEW ZEALAND

The total farm debt in New Zealand is NZ$ 62.3 Billion, which has increased by 270 per cent over the past twenty years and counted for 14 per cent of total bank lending (RBNZ, 2021b). Agriculture sector debts are mostly associated with dairy, sheep and beef, and horticulture farming. The dairy (sheep and beef) sector accounts for 61 (24) per cent of total farm debts worth NZ$ 38.03 (14.92) billion (RBNZ, 2021a).

According to the economic survey of Dairy New Zealand, the term liabilities of the dairy farm debts (including personal debts) have increased by 69 per cent from 2008-09 to 2017-18. In contrast, the average farm size has increased by only 17 per cent. According to this survey, 24 per cent of farmers hold more than 70 per cent debt to asset ratio, and 4% of farmers have more than 90 per cent debt to asset ratio (DairyNZ, 2018).

2.5 Data & Method

2.5.1 DATA

We used two major sources of data for our study: NIWA for weather data and Statistics New Zealand's Longitudinal Business Data (LBD) for financial farm-level data. The LBD is a large micro (unit record) administrative database of all New Zealand businesses, compiled by Statistics New Zealand from data obtained by other government agencies (such as the tax authorities). It has information on six major topics, including agriculture, business financial and tax information, business practices, employment, innovation, and international trade and tourism. We combined the agriculture and business financial datasets. The agricultural data is obtained from agricultural production surveys and the agricultural census starting from 2002. The average response rate of eligible units to the Agriculture Production Surveys is 84% (2002-2018). These respondents produce 87% of the estimated total agricultural output, on average (StatsNZ, 2020). The business financial data is obtained from the IR10 financial statement summary form submitted annually to New Zealand Inland Revenue (IRD) for the processing of tax returns by all businesses.

For weather data, we use the latest version of NZPGI (see section ***2.3*** for details). It is available daily since 1972. We used the NZPGI to identify the drought conditions by defining three thresholds combining the duration and intensity of the drought. If the $20 \leq$ NZPGI ≤ 30 for consecutively 10 to 20 days, it is presumed to have been a mild drought. If the NZPGI ≤ 20 for consecutively 20 or more days, it is identified as a severe drought. We only examined data for the summer season from December to April to identify drought occurrences, since droughts generally do not occur in the rest of the year, nor are they economically meaningful given the agricultural crop cycle in the country during winter. The NZPGI data is available from 11,491 nodes of the virtual climate station network (VCSN) – which is an approximately 5km grid covering the whole of New Zealand.

2.5.2 SAMPLE CONSTRUCTION AND VARIABLES

The LBD sample we analyze includes all businesses identified on Statistics New Zealand's Business Frame as engaging in dairy farming and/or sheep and 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/C) in LBD for the year 2002 - 2018. We used the same APS/C to identify each farm's geographical location at the meshblock level.[1] These unit records were also linked to each farm's financial tax data (Form IR10). We used the tax data to extract information about each farm's debt, its maturity, and other balance sheet variables.

For the NZPGI, we had a daily dataset from 11,491 VCSN grids covering the whole country. Each farm was assumed to be located in the centroid of its respective meshblock and was then linked to the records from its nearest VCSN grid point (See Figure ***2.6*** in section 2.9.1 Appendix – Figures). We used the set of variables described in Table ***2.7*** (in section 2.9.2 Appendix – Tables) as capital structure measures and drought measures to address our research questions.

2.5.3 EMPIRICAL SPECIFICATION

We pursued a micro-econometric approach to study the effects of drought on farm debts and equity that is almost similar to those used by Pourzand et al. (2020) and Timar and Apatov (2020). We used fixed-effect annual panel regressions for pasture-based dairy and sheep/beef farming from 2002-2018. Various measures of farm debt are our dependent variables, whereas

[1] Meshblock are the smallest geographical unit for which data is reported in by Statistics NZ. In 2018, there were more than 50,000 meshblock in New Zealand.

the recording of the occurrence of droughts and their intensities are our primary independent variables. Droughts may have lasting effects on farm debts or equity, so we included lags of up to 2 years for the NZPGI-derived measures of droughts. The models we estimate are:

$$Y_{it} = \alpha + \delta_0 D_{it} + \delta_1 D_{i,t-1} + \delta_2 D_{i,t-2} + c_i + u_{it} \text{ ....} \textbf{Model 1}$$

$$Y_{it} = \alpha + \delta_0 D_{it} + \delta_1 D_{i,t-1} + \delta_2 D_{i,t-2} + \delta_3 CD_{it} + c_i + u_{it} \text{ ....} \textbf{Model 2}$$

Where, Y_{it} is the farm capital structure measures - real short-term debt, real long-term debt, real total debt, farm equity, and related financial measures (profit, and interest payments) - of farm i at time t. D_{it} is the binary variable indicating drought conditions computed through NZPGI for farm i at time t, using the thresholds described above. The farm fixed effects c_i accounts for any unobserved and time-invariant farm heterogeneity that may influence farm debts and may be correlated with current and past drought conditions. u_{it} is an iid error term representing unobserved factors that change over time and affect Y_{it}.

In our second model 2, we add a variable, CD_{it} that measures if there were consecutive droughts (over more than one summer season). The hypothesis that we implicitly test here is that consecutive droughts imply a bigger financial hit to farms than those that are separated by 'good' years, i.e., a farm's balance sheet is more vulnerable to drought if the farm is entering it had been weakened already by a drought episode the year before.

In comparison to Pourzand et al. (2020) and Timar and Apatov (2020), we did not include time-fixed effects in our model as there is a significant temporal correlation between droughts in different regions in NZ. As such, including time effects will only test the importance of droughts hitting a specific region relative to, or more than, the average burden of droughts in the rest of the country in that year/summer[2]. We also used our model for other farm financial

[2] We tested and found a statistically significant auto-correlation in the residuals. To address this issue, according to (Hoechle, 2007; Petersen, 2009; Thompson, 2011), we used

measures (real total equity, real total profit, and real interest payments). We checked for these financial measures to find how the capital structure is changed to meet the financial challenges of farmers during or after drought.

We further stratified our sample into farm sizes based on their total land to evaluate whether the effects of droughts on balance sheets and the capital structure varied across different farm sizes. A farm is categorized as small if its total land area is less than 100 ha and medium if the total land area is between 100 ha and 300 ha. Large farms are those with a land area larger than 300 ha. The financial data is converted to real dollar values by using the GDP implicit price deflator.[3] We winsorized the data at 1%.

2.6 Results

2.6.1 PASTURE DROUGHT STATISTICS

The New Zealand Pasture Growth Index frequency distribution is shown in Figure ***2.2*** (in section 2.9.1 Appendix – Figures). The average value of the index lies between 40-60. The index value remained below 100 in our study period, indicating maximal conditions for pasture growth. Figure ***2.3*** (in section 2.9.1 Appendix – Figures) identifies the occurrence of droughts, as defined by the thresholds described previously.

In 2013, a maximum of 81% of the total grid stations of New Zealand indicated drought conditions, and 12% showed severe drought conditions as shown in Figure ***2.1***.

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robust clustered standard errors. Further discussions on auto-correlation and alternative model test results are presented in section 2.9.2 Appendix – Tables. We took guidance from Kitsios, De Mello, and Matear (2022) to test our alternative model.

[3] GDP implicit deflator shows the rate of price change in the economy as a whole measured as nominal GDP divided by real GDP and multiplied by 100.

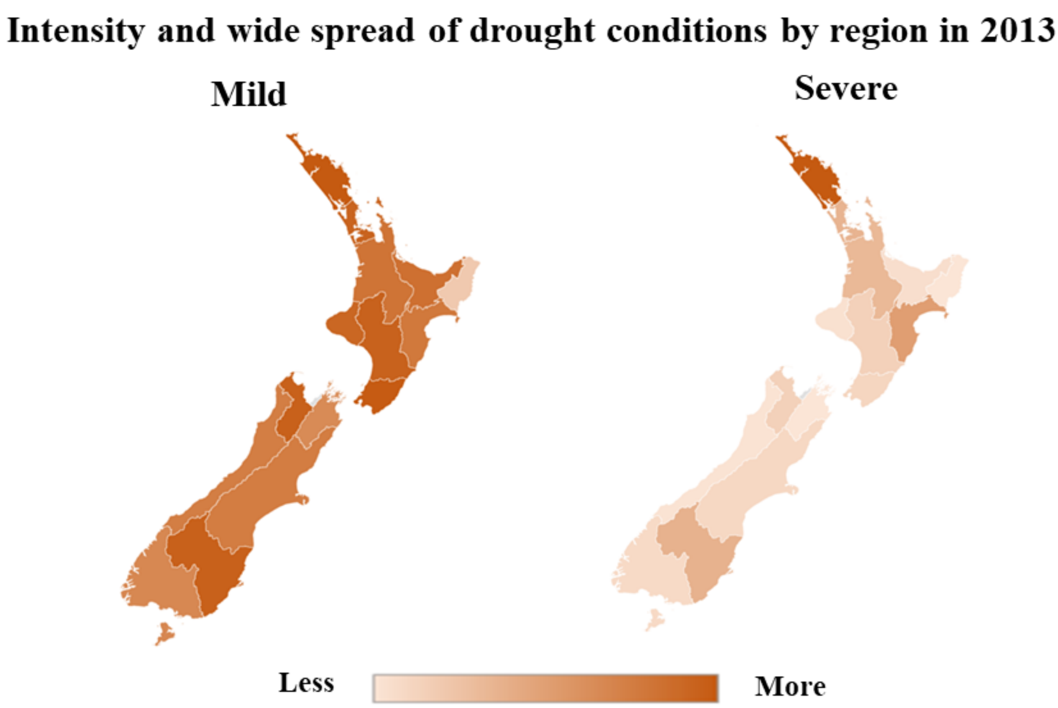

Figure 2.1: Intensity and wide spread of drought conditions by region in 2013[4]

In Figure ***2.4*** (in section 2.9.1 Appendix – Figures), we combined the grid station data into district boundaries for each year and identify the top 10 districts experiencing drought conditions. Southland district is the area hit by drought conditions most frequently from 1997 to 2018. Central Otago and Marlborough are most hit by severe drought conditions for the same period. In Figure ***2.5*** (in section 2.9.1 Appendix – Figures), we identified the number of districts that experienced drought conditions at more than 50 per cent of their grid stations. In 2013 and 2015, most of the districts experienced these drought conditions. The Hurunui district shows drought conditions at all its grid stations in 2015 and 2016.

4 These graphs present the intensity of drought conditions identified by the percentage of drought-affected NCSN within each region. These range from 0-100% grids for mild and 0-63% for severe.

2.6.2 DEBT STATISTICS

Table ***2.1*** describes the statistics for our dataset across all farms and Table ***2.8*** (in section 2.9.2 Appendix – Tables) describes the statistics by different farm sizes.

Table 2.1: Descriptive Statistics by industry across all farms[5]

Variables	Dairy Farming				Sheep and Beef Farming			
	Observations	**No. of Farms**	**Mean**	**SD**	**Observations**	**No. of Farms**	**Mean**	**SD**
				All Farms				
Short-term Debt	26,142	1,746	403	1,324	27,690	1,863	111	504
Long-term Debt	26,142	1,746	1,750	4,183	27,690	1,863	240	1,536
Total Debt	26,142	1,746	2,167	4,774	27,690	1,863	357	1,796
Total Equity	26,142	1,746	2,604	7,528	27,690	1,863	1,111	6,378
Total Profit	26,142	1,746	96	263	27,690	1,863	29	218
Interest Paid	26,142	1,746	120	266	27,690	1,863	16	83
Farmland	25,665	1,743	183.6	176.99	27,237	1,857	266.7	1293.03

Data Source: Statistics NZ

On average, dairy farming is associated with higher real short-term, long-term, and total debt than sheep/beef farming. Similarly, the equity, profit, and interest payments are higher for dairy farms as compared to sheep/beef farms. Dairy farms are, on average, more leveraged than sheep/beef farms. Dairy farms hold 45 per cent debt and 55 per cent equity, on average. Whereas the capital structure of sheep/beef farms consists of 24 per cent debt and 76 per cent equity. On average, interest payments are greater than profits for dairy farms signalling more financial fragility for at least some dairy farms. Whereas the opposite is true for sheep/beef farms.

Small farms hold more equity than debt on average for both dairy and sheep/beef farms. These smaller entities are less reliant on external sources of funds. Whereas medium-size farms hold an approximately equal share of debt and equity, on average, and large farms use more debt

[5] All the values of Mean and SD are in NZD 000 real terms except for the farmland size in a hectare.

than equity in their capital structure, for the dairy sector. The sheep and beef farms largely hold the same low-leveraged capital structure for different farm sizes.

2.6.3 REGRESSION ESTIMATES

We estimate our main equation for capital structure variables as debt and equity measures at two different intensities of droughts from mild to severe and both. The debt measures include real short-term debt, real long-term debt, and real total debt, and other measures include total equity, total profit, and cost of debt as interest paid. We estimated our model for the full sample and subsamples categorized by farm sizes. In model (1) we didn't include the variable denoting consecutive drought seasons, whereas in the model (2) we used both time-lagged drought indicators and the consecutive drought indicator. The estimation results for all measures for dairy farming and sheep and beef farming are discussed separately in the following sections.

2.6.4 DEBT MEASURE RESULTS

The regression results of the impacts of different drought conditions on debt for all dairy farming are shown in Table ***2.2***. The results show a positive and significant impact of all drought conditions on the real short-term debt contemporaneously ($p<0.05$). The positive impact for the next two years after the drought ($\delta_{Drought\ (t-1)} = 50.28$, $p<0.05$ and $\delta_{Drought\ (t-2)} = 86.31$, $p<0.01$) on real short-term debt of dairy farms was stronger than the positive impact for contemporaneous drought ($\delta_{Drought\ (t)} = 33$, $p<0.05$). The same results were found for long-term and total debt. It indicates that dairy farmers borrow more money after drought conditions.

When we separated the drought measure into mild and severe drought, the findings highlighted the estimated coefficients during the severe droughts were statistically insignificant for short-term debt[6] ($\delta_{Drought\ (t)} = 46.52$, $p>0.10$) whereas the estimated coefficient of the long-term debt

[6] Possibly, this result arises because dairy prices increase during severe droughts, as these are more widespread and hit many more farms concurrently.

is positive and statistically significant ($\delta_{Drought\ (t)}$ = 186.26, p<0.01), implying dairy farmers are relying more on long-term borrowings during severe droughts. The regression results for total debt for dairy farming are commensurate with the results for short- and long-term debts, for both mild and severe drought conditions, and all-time lags. The results remain consistent when we controlled for consecutive droughts in model 2. These estimated results suggest that droughts increased the debt of dairy farmers ranging from NZD 33,000 to NZD 326,850.

Table 2.2: Regression results for Debt of Dairy Farming (NZD in 000)

Indicators	**Short-term Debt**		**Long-term Debt**		**Total Debt**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	33.00** (16.67)	32.60* (16.96)	59.31** (27.73)	68.06** (28.14)	76.66** (34.59)	84.77** (34.84)
Drought (t-1)	50.28** (20.14)	49.92** (20.09)	67.02** (31.49)	74.87** (31.78)	106.54*** (39.06)	113.81*** (39.00)
Drought (t-2)	86.31*** (15.61)	85.99*** (15.42)	133.91*** (42.11)	140.99*** (42.00)	213.36*** (43.10)	219.92*** (42.83)
Cons. Drought		-0.64 (3.56)		14.01*** (4.98)		12.98** (5.67)
Obs	26,142	26,142	26,142	26,142	26,142	26,142
Adj R-Sq	0.4341	0.4341	0.7811	0.7812	0.7911	0.7911
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	30.72* (17.50)	28.67 (17.87)	44.90 (30.94)	54.97* (31.48)	61.53 (38.03)	69.26* (38.41)
Drought (t-1)	54.92** (21.53)	52.55** (21.55)	72.31** (33.12)	83.95** (33.76)	117.10*** (41.91)	126.02*** (42.01)
Drought (t-2)	86.06*** (16.39)	84.25*** (16.16)	131.17*** (48.67)	140.04*** (48.57)	209.85*** (49.53)	216.66*** (49.24)
Cons. Drought		-3.06 (3.61)		15.03*** (5.48)		11.53* (6.14)
Obs	24,111	24,111	24,111	24,111	24,111	24,111
Adj R-Sq	0.3978	0.3978	0.7756	0.7757	0.7859	0.786
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	46.52 (28.78)	47.56 (28.92)	186.26*** (70.50)	158.49** (71.05)	200.42** (86.28)	174.78** (87.15)
Drought (t-1)	80.83*** (31.00)	78.49** (30.83)	91.29*** (32.19)	153.35*** (34.99)	149.95*** (45.80)	207.24*** (46.78)
Drought (t-2)	104.59*** (19.19)	102.97*** (19.90)	188.94*** (47.00)	231.96*** (48.06)	287.14*** (53.20)	326.85*** (54.87)
Cons. Drought		-1.04 (3.03)		27.69*** (6.30)		25.56*** (6.72)
Obs	16,980	16,980	16,980	16,980	16,980	16,980
Adj R-Sq	0.4351	0.435	0.8193	0.8196	0.8249	0.8251

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

Table ***2.9*** to Table ***2.11*** (in section 2.9.2 Appendix – Tables) presents the results for all forms of debts at different dairy farm sizes. These results show that small and especially medium-size farms experience an increase in short-term debt in the aftermath of droughts. Medium-size farms see a higher increase in their debt levels than do small farms, and the increase is larger for more severe droughts, though there are less consistent results for the contemporaneous impact of the droughts. However, at the first lag (t-1) and second lag (t-2), the impact for the medium-size farm is statistically significant and for small-size farms, the results are statistically significant at the second lag (t-2) under severe drought conditions. The medium-sized farms show a slight increase in short-term debt if previously experienced drought season and are now under severe drought. We have not found any statistically significant impact on short-term debt for large farms under any drought intensity at any time. It appears that large farms can weather drought conditions (even more severe ones) without much additional short-term borrowing, in contrast with small and medium-sized farms. We have also not recorded any statistically significant impact of droughts on the long-term debt of large farms. The medium size farms do accumulate more long-term debt in the two years following the drought; and with some evidence of a delayed accumulation of debt after two years, for large farms. The results for total debt remain mostly consistent for small-size and medium-size farms and we have not found any statistical significance impact for large-size farms.

Furthermore, our results show an additional increase in debt levels associated with consecutive drought seasons. Medium-sized farms are more affected than small farms and impacts are larger for them under severe drought conditions.

Table ***2.3*** presents the equivalent results for sheep and beef farms for the same dependent variables as in Table ***2.2***. The results show the statistically significant positive impact of drought on short-term debt for the full sample. The estimated coefficients, however, are smaller than for the dairy farms and statistically significant. Furthermore, the regression results show no statistically significant impact of droughts on long-term debt. These estimated results suggest that droughts increased the short-term debt of sheep and beef farmers ranging from NZD 9,620 to NZD 44,960.

Table 2.3: Regression results for Debt of Sheep/Beef Farming (NZD in 000)

Indicators	**Short-term Debt**		**Long-term Debt**		**Total Debt**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	13.57***	14.54***	2.15	6.49	11.40*	16.84**
	(3.99)	(4.02)	(4.72)	(4.91)	(6.91)	(6.95)
Drought (t-1)	14.41***	15.36***	-0.43	3.77	9.86	15.13*
	(5.52)	(5.71)	(5.88)	(5.81)	(8.37)	(8.36)
Drought (t-2)	15.40***	16.07***	-1.73	1.24	10.05	13.77
	(5.71)	(5.73)	(5.88)	(5.82)	(8.66)	(8.61)
Cons. Drought		1.84		8.20**		10.29***
		(1.22)		(3.46)		(3.58)
Obs	27,690	27,690	27,690	27,690	27,690	27,690
Adj R-Sq	0.565	0.5651	0.9034	0.9036	0.8697	0.8698
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	11.72**	12.57***	0.81	5.35	8.48	14.07*
	(4.59)	(4.61)	(4.92)	(4.94)	(7.50)	(7.43)
Drought (t-1)	15.08***	16.15***	-1.38	4.33	9.47	16.51**
	(5.17)	(5.49)	(6.03)	(5.79)	(8.40)	(8.35)
Drought (t-2)	17.43***	18.13***	-2.66	1.05	10.80	15.38*
	(5.57)	(5.69)	(6.06)	(5.87)	(8.71)	(8.61)
Cons. Drought		1.47		7.80**		9.62***
		(1.27)		(3.02)		(3.27)
Obs	25,560	25,560	25,560	25,560	25,560	25,560
Adj R-Sq	0.4873	0.4874	0.9111	0.9112	0.8719	0.8721
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	30.19***	29.59***	19.06	8.32	44.96***	34.04**
	(9.53)	(9.67)	(14.31)	(14.66)	(16.56)	(17.12)
Drought (t-1)	9.59*	10.66*	-6.40	12.56	-2.47	16.81
	(4.96)	(5.91)	(6.66)	(8.46)	(8.93)	(11.26)
Drought (t-2)	15.37***	16.06***	-7.92	4.27	-0.77	11.63
	(5.57)	(5.76)	(6.88)	(7.18)	(11.14)	(11.79)
Cons. Drought		0.50		8.83**		8.98**
		(1.40)		(3.95)		(4.31)
Obs	17,244	17,244	17,244	17,244	17,244	17,244
Adj R-Sq	0.7313	0.7313	0.6032	0.6039	0.5982	0.5985

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 for all forms of debts at different farm size levels of sheep/beef farming are presented in Table ***2.12*** to Table ***2.14*** (in section 2.9.2 Appendix – Tables). The impact is statistically significant for large-size farms only, indicating that the large sheep and beef farmers remain active short-term borrowers during and after different levels of drought conditions, but those smaller producers seem to access the debt market less. There is some evidence, however, of an increase in long-term debt for small and large sheep/beef farmers if they experience more than one consecutive drought season. One possible reason for the less statistically significant impact of droughts on debt in the sheep and beef industry may be the selling of stock as a coping strategy (Timar & Apatov, 2020).

The sheep and beef farmers didn't show any statistically significant impact at all and mild drought conditions on total debts for small-size farms, and medium-size farms. The large-size farms show a statistically significant positive impact on total debt during droughts and severe drought conditions under model (1) and increased coefficient values and statistically significant impact during and after droughts in the model (2).

2.6.5 RESULTS FOR EQUITY AND OTHER FINANCIAL VARIABLES

We have found statistically significant use of debt during and in the aftermath of droughts. We further examine the evolution of the alternative source of capital – equity – and also profitability, and cost of funding. The equity is tested to analyse the farmers' use of their own financial resources, as an alternative to borrowing, during or after droughts. The estimation results of these variables for dairy farming, and sheep and beef farming are shown in Table ***2.4*** and Table ***2.5***, respectively.

Table ***2.4*** shows a positive and statistically significant increase in equity for dairy farms. The estimated coefficient values of the contemporaneous increase in equity are higher than the increase in total debt for dairy farmers. At first, then, the dairy farmers start investing their own resources to meet the drought challenge. But their reliance on external debt funding increases later more than their equity investments. During and after severe droughts, we found larger positive coefficients for both equity and debts. Maybe not surprisingly, we found that dairy farmers are more in need of both equity and debt funding after severe drought conditions, and they utilize both funding options.

To examine whether the need for additional funding is partly, at least, a result of declining profits, we estimated coefficients for specifications examining the correlates of real profit as the dependent variable. Coefficients for the drought measure, at all lags, are negative and statistically significant. This is noteworthy, as, in comparison to findings by Pourzand et al. (2020) who found a positive correlation with their drought measure, we found a negative impact of droughts (as measured by the NZPGI) on dairy farms' profitability.

We also find evidence of a positive effect of droughts on the interest costs of debts for dairy, suggesting an increase in debts increases the interest payments and is one of the reasons profits are lower post-drought.

Table 2.4: Regression results for other financials of Dairy Farming (NZD in 000)

Indicators	**Total Equity**		**Total Profit**		**Total Interest**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	147.43*** (44.01)	162.22*** (45.07)	-21.72*** (3.71)	-22.82*** (3.72)	4.59** (2.05)	5.48*** (2.04)
Drought (t-1)	172.39** (75.06)	185.66** (74.79)	-8.69*** (3.29)	-9.67*** (3.30)	0.72 (3.21)	1.51 (3.19)
Drought (t-2)	136.96*** (45.67)	148.94*** (46.34)	-35.59*** (4.09)	-36.48*** (4.10)	7.96** (3.42)	8.68** (3.37)
Cons. Drought		23.68*** (7.39)		-1.76*** (0.54)		1.43*** (0.37)
Obs	26,142	26,142	26,142	26,142	26,142	26,142
Adj R-Sq	0.8007	0.8007	0.2535	0.2537	0.7365	0.7367
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	134.17*** (44.17)	150.70*** (45.22)	-23.65*** (3.97)	-25.06*** (3.98)	4.23** (2.12)	5.30** (2.12)
Drought (t-1)	216.58** (80.49)	235.67*** (80.06)	-8.38** (3.50)	-10.00*** (3.52)	0.60 (3.41)	1.84 (3.40)
Drought (t-2)	134.87** (52.52)	149.42*** (53.37)	-32.59*** (4.30)	-33.83*** (4.31)	8.16** (3.84)	9.10** (3.79)
Cons. Drought		24.66*** (7.16)		-2.10*** (0.50)		1.60*** (0.41)
Obs	24,111	24,111	24,111	24,111	24,111	24,111
Adj R-Sq	0.7996	0.7997	0.2563	0.2567	0.7285	0.7287
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						

Drought (t)	217.79** (93.99)	173.64* (94.70)	-23.84*** (7.65)	-21.92*** (7.64)	8.50* (4.37)	6.41 (4.45)
Drought (t-1)	197.78* (101.19)	296.44*** (102.49)	-20.91*** (5.00)	-25.20*** (5.17)	2.79 (3.40)	7.47** (3.43)
Drought (t-2)	269.25*** (58.65)	337.64*** (60.47)	-33.40*** (5.04)	-36.38*** (5.21)	7.54** (3.53)	10.78*** (3.55)
Cons. Drought		44.03*** (7.61)		-1.91*** (0.72)		2.09*** (0.47)
Obs	16,980	16,980	16,980	16,980	16,980	16,980
Adj R-Sq	0.7987	0.7989	0.2737	0.2741	0.7878	0.7883

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

Table ***2.15*** to Table ***2.17*** (in section 2.9.2 Appendix – Tables) present the results for equity, profitability, and cost of funds at different farm sizes. The estimated coefficients for the equity for small-size dairy farming at all time lags are positive and statistically significant. Medium-sized farms invest more in equity if they experienced severe and consecutive droughts, and we found no statistically significant impact of droughts on large dairy farms' equity.

The results of real profit as a dependent variable remain consistent for all size farm categories, the intensity of drought, and the continuous occurrence of drought seasons. Profits universally decrease. While for the small and medium-sized farms we find a statistically significant increase in interest payments, the large farms are not increasing their borrowing during and after droughts same, so there is also no statistically significant evidence for any change in their interest payments.

Table ***2.5*** provides the equivalent estimation of equity, profitability, and cost of funds for sheep/beef farming. We didn’t find any statistically significant impact of droughts on sheep/beef farmers' equity concurrently, and for the first lag, whereas, for the second lag (t-2), there is a statistically significant increase in equity. The results of profitability for sheep/beef farming show no statistically significant impact of droughts. However, there is a statistically significant reduction in profits during severe drought conditions. There is no statistically significant impact of droughts found on sheep/beef farms' cost of debt.

Table 2.5: Regression results for other financials of Sheep/Beef Farming (NZD in 000)

Indicators	Total Equity		Total Profit		Total Interest	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	30.87 (31.50)	34.63 (30.01)	1.12 (5.26)	0.87 (5.11)	0.21 (0.26)	0.32 (0.29)
Drought (t-1)	27.46 (41.52)	31.11 (40.38)	1.43 (1.73)	1.19 (1.61)	-0.16 (0.29)	-0.05 (0.31)
Drought (t-2)	83.42** (37.75)	86.00** (36.46)	0.93 (2.29)	0.76 (2.20)	-0.13 (0.28)	-0.05 (0.29)
Cons. Drought		7.12 (6.36)		-0.47 (0.50)		0.20 (0.19)
Obs	27,690	27,690	27,690	27,690	27,690	27,690
Adj R-Sq	0.901	0.901	0.2023	0.2023	0.8852	0.8853
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	31.10 (33.50)	34.94 (31.70)	2.23 (5.53)	1.86 (5.35)	0.18 (0.26)	0.31 (0.28)
Drought (t-1)	29.31 (44.07)	34.14 (42.48)	2.23 (1.89)	1.78 (1.74)	-0.30 (0.28)	-0.14 (0.30)
Drought (t-2)	92.17** (40.49)	95.31** (38.71)	1.86 (2.25)	1.57 (2.10)	-0.12 (0.28)	-0.02 (0.28)
Cons. Drought		6.60 (6.16)		-0.63 (0.51)		0.22 (0.15)
Obs	25,560	25,560	25,560	25,560	25,560	25,560
Adj R-Sq	0.9014	0.9014	0.2282	0.2282	0.8974	0.8975
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	-25.65 (30.27)	-51.03 (30.45)	-13.94*** (3.66)	-14.24*** (3.60)	1.13 (0.83)	0.90 (0.86)
Drought (t-1)	99.40 (74.24)	144.21* (74.39)	6.43 (4.98)	6.96 (5.10)	-0.41 (0.32)	0.01 (0.57)
Drought (t-2)	92.40* (48.26)	121.22** (48.26)	-1.78 (2.85)	-1.43 (3.16)	-0.19 (0.37)	0.08 (0.47)
Cons. Drought		20.86*** (5.82)		0.25 (0.54)		0.19 (0.23)
Obs	17,244	17,244	17,244	17,244	17,244	17,244
Adj R-Sq	0.6793	0.6795	0.1282	0.1282	0.7617	0.7618

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 for equity, profitability and cost of funds at different farm sizes of sheep/beef farms are presented in Table ***2.18*** to Table ***2.20*** (in section 2.9.2 Appendix – Tables). We found a statistically significant impact of droughts on small-sized sheep/beef farmers' equity at the second lag (t-2), and a statistically significant increase in equity of small and medium farms for severe and consecutive droughts. Similar to large dairy farmers, we didn’t find any statistical significance impact of droughts on the equity of large sheep/beef farms. However, there is a statistically significant reduction in profits during severe drought conditions for large sheep/beef farms. The statistically significant impact of severe droughts on small, medium, and large farms' profitability remains consistent as we control for consecutive drought seasons. There is no statistically significant impact of droughts found on sheep/beef farmers' cost of debt.

2.6.6 ROBUSTNESS CHECK

We used an alternative set of soil moisture-based drought indicators to run regressions and test whether our results are sensitive to the use of specific drought measures. We used daily potential evapotranspiration deficit (PED) data from 11,491 virtual climate station network (VCSN) (~5km) grids covering the whole of New Zealand from the year 2000 to 2020. PED has measured the gap between water demand and the actual availability of water in millimetres. Meteorologists consider PED a useful means of ranking the severity of dry periods (NIWA, 2007a). We used the thresholds of PED to identify the intensity of drought conditions based on a rule of thumb defined by NIWA - an accumulation of 30 mm more PED corresponds to an extra week of reduced grass growth (A Mol, A Tait, & G Macara, 2017; NIWA, 2007a). Therefore, we accumulated the PED from December to April to identify the severity of the dry period each year. The drought is identified if cumulative PED $\geq$ 250mm, the mild drought conditions are identified if cumulative 250mm$\leq$PED $\leq$ 320mm, and the severe drought occurs if cumulative PED>320mm. The regression results for both dairy and sheep/beef farming for debt and non-debt measures are summarized in Table ***2.21*** to Table ***2.24*** (in section 2.9.2 Appendix – Tables).

We found almost similar results to the prior findings, the coefficients in the robustness test model represent similar signs and statistical significance. Our results appear robust to this alternative drought measure. We worked with the inclusion of a control variable in our model too, such as farm size. The new results are present in Table ***2.25*** to Table ***2.32*** (in section 2.9.2 Appendix – Tables). Our results remain consistent through controlling farm size in our model.

Further, we also tested our model using NZDI. The daily data for NZDI was available from the year 2007 to 2018 at the district level. We found mixed results as compared to our original results. The results are presented in Table ***2.33*** to Table ***2.48*** (in section 2.9.2 Appendix – Tables). This to some extent is in line with Pourzand et al. (2020) results and indicates that our measure of NZPGI is maybe more suitable for the measurement of the challenges that droughts pose to the dairy and sheep/beef sectors in New Zealand.

2.7 Conclusion

This study empirically examined the impacts of droughts, measured using NZPGI in New Zealand, on pasture-reliant farms' debts and equity. We used dairy, and sheep/beef farms' financial unit records for seventeen years to identify changes in their capital structure. We investigated if the farms' borrowings, use of equity funding, and associated costs to these sources change during or after drought conditions. Our results show a statistically significant increase in short-term and long-term debts, equity, and the cost of debt for dairy farming in the aftermath of droughts. Whereas the results show a statistically significant negative impact of droughts on the profitability of dairy farming. Furthermore, the occurrence of consecutive droughts increases their impact on farms' capital structure. These results show that dairy farms face more financial strain during and after droughts and need to rely on both equity and debt financing.

In comparison, our results show a statistically significant increase of only short-term debt for sheep and beef farms after droughts, and a negative impact of only severe drought conditions on the profitability of sheep and beef farms. It seems that sheep/beef farms face fewer financial challenges during and after drought conditions, possibly because they are significantly less leveraged. The results by farm size categories show that it is the small dairy farms that rely more on equity funding and short-term borrowing during and after drought conditions. Large dairy farms appear financially more resilient to drought conditions.

In comparison to dairy farms, the large sheep/beef farms remain active borrowers during and after different levels of drought conditions. They also face a reduction in profitability during severe drought conditions. Whereas the small sheep/beef farmers invest more after a drought.

We tested one link in the chain from droughts to financial fragility. We examined the link between droughts to an increase in equity/debts in a potential causal chain of droughts, debts and productivity/ performance, and then systemic lenders (banks) fragility. Future research may empirically explore the next stages in this causal from debt/equity to farm financial performance and banking sector profitability; as in most cases, it is banks that are the main source of lending for farms, in New Zealand and elsewhere.

Of course, all of this research is relevant to our concerns about climate change modifying the likelihoods, durations and intensities of droughts as they are experienced in New Zealand. However, there is a lot of uncertainty in our knowledge with respect to the onset and duration of droughts in general, and the impact climate change will have on these processes. The IPCC — Intergovernmental Panel on Climate Change projects an intensification of the hydrological cycle, with more precipitation-related extremes (both extreme wet and extreme dry events). As such, we do not try and project the implications of our estimations for future impacts of climate change on farms' capital structure through the drought channel. We leave these efforts for future research.

2.8 References

Bernknopf, R., Brookshire, D., Kuwayama, Y., Macauley, M., Rodell, M., Thompson, A., . . . Zaitchik, B. (2018). The value of remotely sensed information: The case of a GRACE-enhanced drought severity index. *Weather, Climate, and Society, 10*(1), 187-203.

Butcher, G., & Ford, S. (2009). *Modeling the regional economic impacts of the 2007/08 drought: results and lessons*. Retrieved from https://www.rbnz.govt.nz/research-and-publications/analytical-notes/2013/an2013-02

DairyNZ. (2018). *DairyNZ Economic Survey 2017-18*. Retrieved from https://www.dairynz.co.nz/publications/dairy-industry/dairynz-economic-survey-2017-18/

Do, V., Nguyen, T. H., Truong, C., & Vu, T. (2021). Is drought risk priced in private debt contracts? *International Review of Finance, 21*(2), 724-737.

Dorigo, E., & Ballingall, J. (2020). *Dairy's economic contribution 2020 update*. Retrieved from https://www.dcanz.com/about-the-nz-dairy-industry/

Edwards, B., Gray, M., & Hunter, B. (2009). A sunburnt country: the economic and financial impact of drought on rural and regional families in Australia in an era of climate change. *Australian Journal of Labour Economics, 12*(1), 109-131.

Godfrey, S. S., Nordblom, T., Ip, R. H., Robertson, S., Hutchings, T., & Behrendt, K. (2021). Drought shocks and gearing impacts on the profitability of sheep farming. *Agriculture, 11*(4), 366.

Greig, B., Nuthall, P., & Old, K. (2019). Resilience and finances on Aotearoa New Zealand farms: Evidence from a random survey on the sources and uses of debt. *New Zealand Geographer, 75*(1), 21-33.

Hill, M. J., Donald, G. E., Hyder, M. W., & Smith, R. C. (2004). Estimation of pasture growth rate in the south west of Western Australia from AVHRR NDVI and climate data. *Remote sensing of environment, 93*(4), 528-545.

Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. *The stata journal, 7*(3), 281-312.

Hollinger, S., Isard, S., & Welford, M. (1993). *A new soil moisture drought index for predicting crop yields.* Paper presented at the Preprints, Eighth Conference on Applied Climatology.

Huynh, T. D., Nguyen, T. H., & Truong, C. (2020). Climate risk: The price of drought. *Journal of Corporate Finance, 65*, 101750.

Kamber, G., McDonald, C., & Price, G. (2013). *Drying out: Investigating the economic effects of drought in New Zealand*. Retrieved from https://www.rbnz.govt.nz/research-and-publications/analytical-notes/2013/an2013-02

Kingwell, R. S., & Xayavong, V. (2017). How drought affects the financial characteristics of Australian farm businesses. *Australian Journal of Agricultural and Resource Economics, 61*(3), 344-366.

Kitsios, V., De Mello, L., & Matear, R. (2022). Forecasting commodity returns by exploiting climate model forecasts of the El Niño Southern Oscillation. *Environmental Data Science, 1*.

Kuwayama, Y., Thompson, A., Bernknopf, R., Zaitchik, B., & Vail, P. (2019). Estimating the impact of drought on agriculture using the US Drought Monitor. *American Journal of Agricultural Economics, 101*(1), 193-210.

Lawes, R., & Kingwell, R. (2012). A longitudinal examination of business performance indicators for drought-affected farms. *Agricultural Systems, 106*(1), 94-101.

Lesk, C., Rowhani, P., & Ramankutty, N. (2016). Influence of extreme weather disasters on global crop production. *Nature, 529*(7584), 84-87.
Liu, W. T., & Kogan, F. N. (1996). Monitoring regional drought using the Vegetation Condition Index. *International Journal of Remote Sensing, 17*(14), 2761-2782. doi:10.1080/01431169608949106
Ma, W., Renwick, A., & Zhou, X. (2020). The relationship between farm debt and dairy productivity and profitability in New Zealand. *Journal of Dairy Science, 103*(9), 8251-8256.
McKee, T. B., Doesken, N. J., & Kleist, J. (1993). *The relationship of drought frequency and duration to time scales.* Paper presented at the Proceedings of the 8th Conference on Applied Climatology.
Meyer, S., & Hubbard, K. (1995). *Extending the crop-specific drought index to soybean.* Paper presented at the Preprints, Ninth Conf. on Applied Climatology, Dallas, TX, Amer. Meteor. Soc.
Ministry for the Environment. (2001). Managing Waterways on Farms: A guide to sustainable water and riparian management in rural New Zealand. Retrieved from https://www.mfe.govt.nz/sites/default/files/managing-waterways
Ministry for the Environment. (2018). *Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment, 2nd Edition.* Retrieved from Wellington: https://environment.govt.nz/publications/climate-change-projections-for-new-zealand/
Ministry for the Environment and StatsNZ. (2017). *New Zealand's Environmental Reporting Series: Our atmosphere and climate 2017*. Retrieved from www.mfe.govt.nz and www.stats.govt.nz
Mishra, A. K., & Singh, V. P. (2010). A review of drought concepts. *Journal of hydrology, 391*(1-2), 202-216.
Mol, A., Tait, A., & Macara, G. (2017). An automated drought monitoring system for New Zealand. *Weather and Climate, 37*(1), 23-36.
Mugera, A. W., & Nyambane, G. G. (2015). Impact of debt structure on production efficiency and financial performance of B roadacre farms in W estern A ustralia. *Australian Journal of Agricultural and Resource Economics*, *59*(2), 208-224.
NASA. (2000). Measuring Vegetation, NDVI as an Indicator of Drought. Retrieved from https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_3.php
National Institute of Water & Atmospheric Research Ltd. (2007a). Backgrounder. Retrieved from https://niwa.co.nz/climate/nzcu/climate-update-73-july-2005/backgrounder
National Institute of Water & Atmospheric Research Ltd. (2007b). New Zealand glaciers shrinking. Retrieved from https://niwa.co.nz/news/new-zealand-glaciers-shrinking
National Institute of Water & Atmospheric Research Ltd. (2017). New Zealand Drought Index and Drought Monitor Framework. Retrieved from https://niwa.co.nz/climate/information-and-resources/drought-monitor
National Institute of Water & Atmospheric Research Ltd. (2019). Droughts. Retrieved from NIWA Climate, Freshwater & Ocean Science. Retrieved from https://niwa.co.nz/natural-hazards/hazards/droughts
Naumann, G., Cammalleri, C., Mentaschi, L., & Feyen, L. (2021). Increased economic drought impacts in Europe with anthropogenic warming. *Nature Climate Change*, 1-7.
New Zealand Government. (2016). *NEW ZEALAND Economic and Financial Overview 2016*. Retrieved from https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf
New Zealand's Exchange. (2019). Dairy data and insights. Retrieved from https://www.nzx.com/products/nzx-dairy-data

OECD. (2016). *Mitigating Droughts and Floods in Agriculture Policy Lessons and Approaches*. OECD Studies on Water: https://doi.org/10.1787/9789264246744-en.

Palmer, W. C. (1965). *Meteorological drought* (Vol. 30): US Department of Commerce, Weather Bureau.

Pasture.io. (2020). Managing your beef, cattle, dairy or sheep farm during a drought. Retrieved from https://pasture.io/farm-land-management/beef-cattle-dairy-sheep-during-drought

Petersen, M. A. (2009). Estimating standard errors in finance panel data sets: Comparing approaches. *The Review of Financial Studies*, *22*(1), 435-480. doi:https://doi.org/10.1093/rfs/hhn053

Pourzand, F., Noy, I., & Sağlam, Y. (2020). Droughts and farms' financial performance: a farm-level study in New Zealand. *Australian Journal of Agricultural and Resource Economics*, *64*(3), 818-844. doi:10.1111/1467-8489.12367

Reserve Bank of New Zealand. (2019). *Financial Stability Report May 2019*. Retrieved from https://www.rbnz.govt.nz/financial-stability/financial-stability-report

Reserve Bank of New Zealand. (2021a). *Financial Stability Report May 2021*. Retrieved from https://www.rbnz.govt.nz/financial-stability/financial-stability-report

Reserve Bank of New Zealand. (2021b). Sector lending (registered banks and non-bank lending institutions) - C5. Retrieved from https://www.rbnz.govt.nz/statistics/c5

Shafer, B. A., & Dezman, L. E. (1982). *Development of a surface water supply index (SWSI) to assess the severity of drought conditions in snowpack runoff areas.* Paper presented at the 50th Annual Western Snow Conference, Reno, Nevada.

StatsNZ. (2020). DataInfo Explore our metadata. Retrieved from Stats NZ. Retrieved from http://datainfoplus.stats.govt.nz/Item/nz.govt.stats/6362a469-f374-412e-ac25-d76fd0962003?_ga=2.200814957.27964671.1579133158-755302910.1568947329#

StatsNZ. (2021). Which industries contributed to New Zealand's GDP? Retrieved from https://www.stats.govt.nz/tools/which-industries-contributed-to-new-zealands-gdp

Stone, D. a. i., Carey-Smith, T., Dean, S., Harrington, L., & Storey, B. (2019). *The impact of greenhouse gas emissions on recent low pasture supply events.* Paper presented at the Meteorological Society of NZ Annual Conference, Victoria University of Wellington, New Zealand.

Thompson, S. B. (2011). Simple formulas for standard errors that cluster by both firm and time. *Journal of financial economics*, *99*(1), 1-10.

Timar, L., & Apatov, E. (2020). *A Growing Problem: Exploring Livestock Farm Resilience to Droughts in Unit Record Data*. Motu Working Paper 20-14. Motu Economic and Public Policy Research. Wellington, New Zealand.

Tran, L. T., Stoeckl, N., Esparon, M., & Jarvis, D. (2016). If climate change means more intense and more frequent drought, what will that mean for agricultural production? A case study in Northern Australia. *Australasian Journal of Environmental Management*, *23*(3), 281-297.

Weier, J., & Herring, D. (2000). Measuring vegetation (NDVI & EVI). *NASA Earth Observatory*, *20*.

2.9 Appendices

2.9.1 APPENDIX - FIGURES

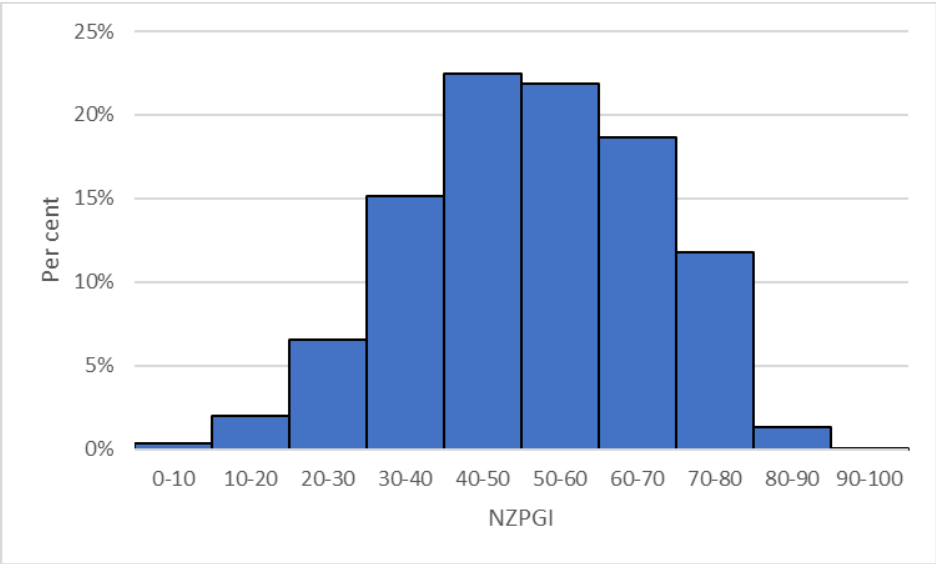

Figure 2.2: The frequency distribution of NZPGI

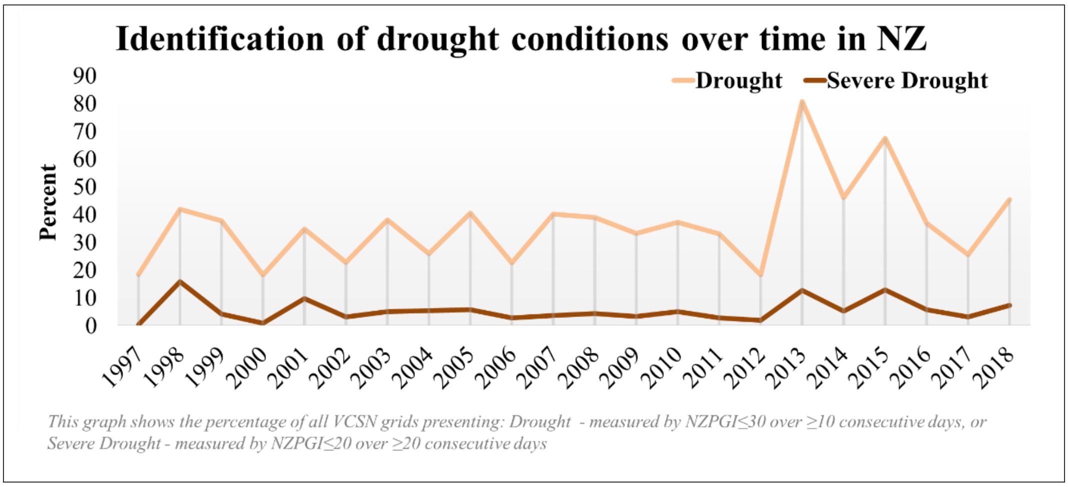

Figure 2.3: Identification of drought conditions at two levels over the years in New Zealand

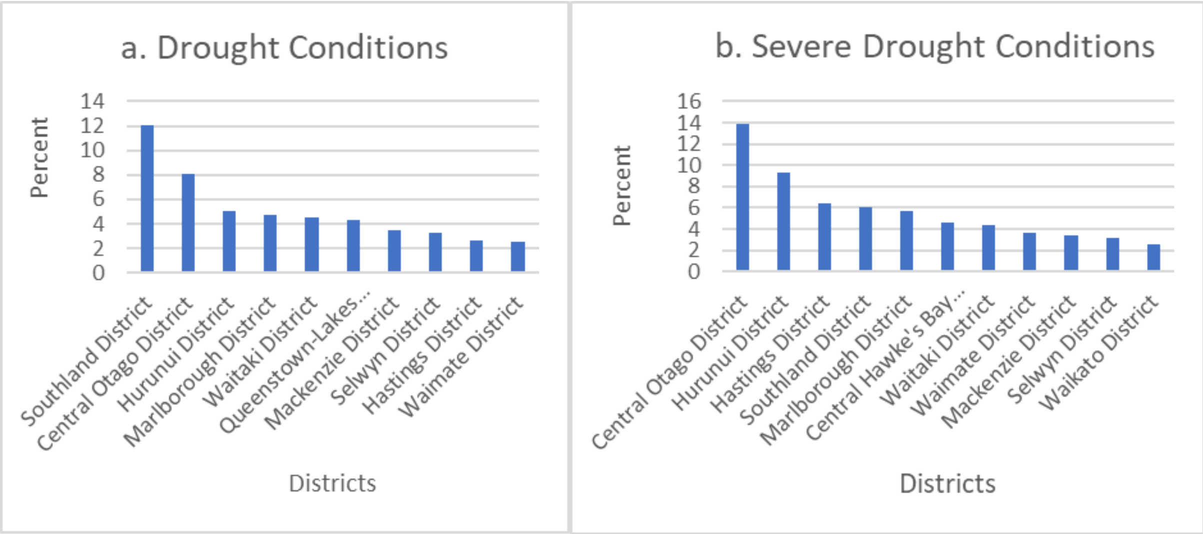

Figure 2.4: The top districts hit by different levels of drought conditions

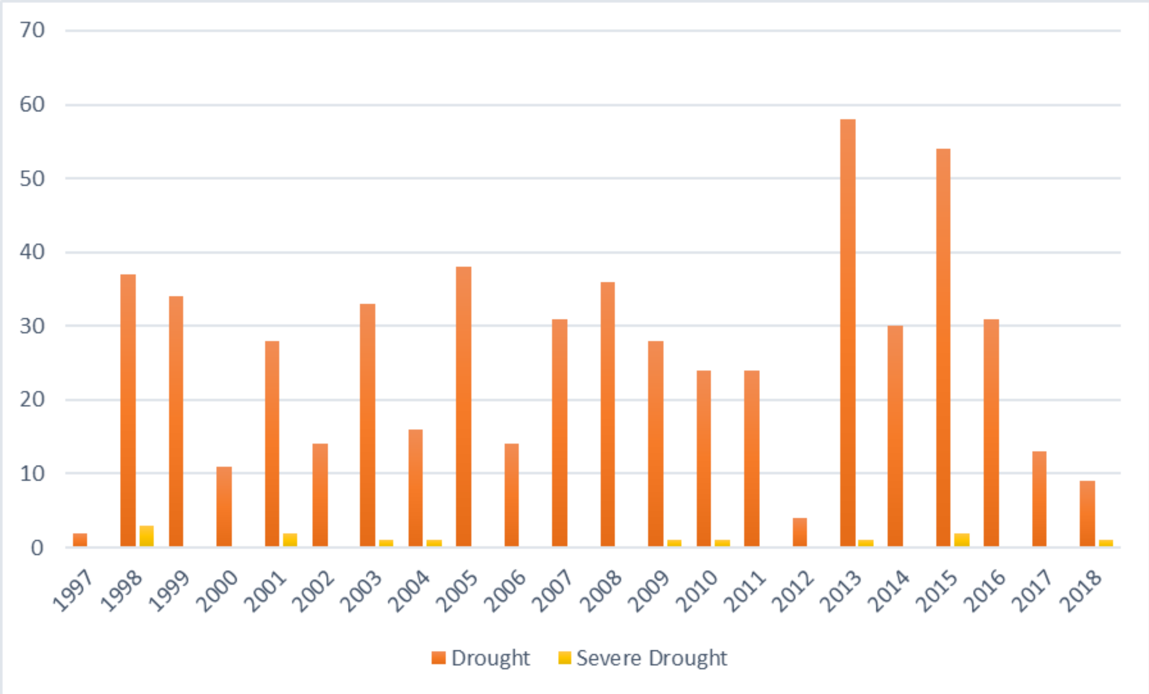

Figure 2.5: No. of Districts experiencing drought conditions at more than 50 per cent of their grid stations

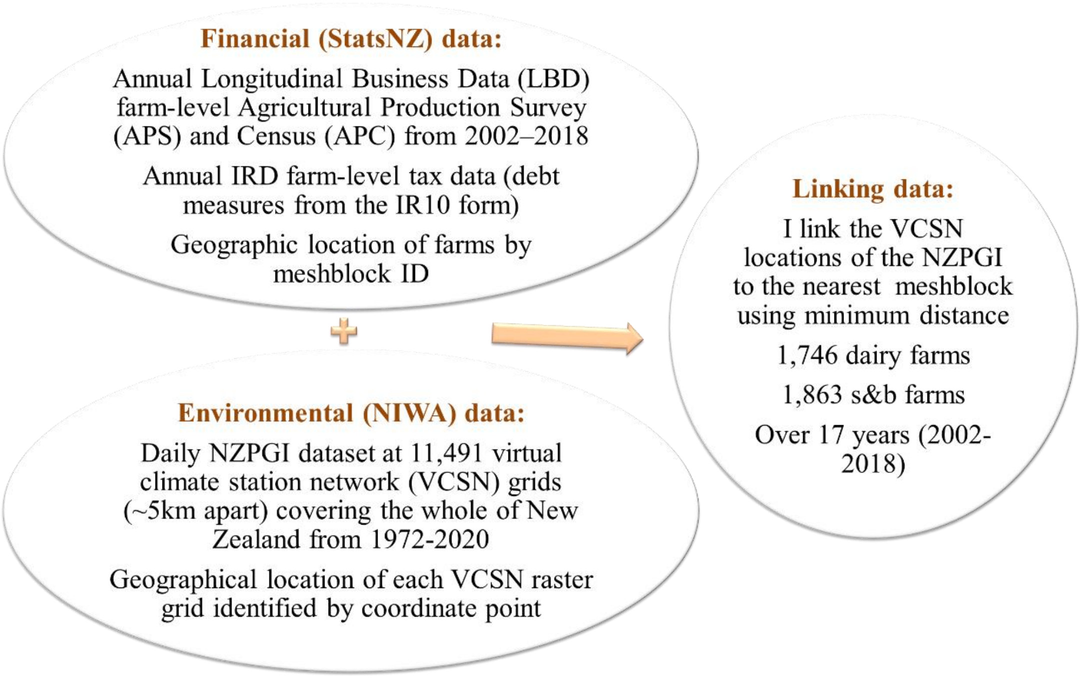

Figure 2.6: Sample construction and Linkage

2.9.2 APPENDIX - TABLES

Table 2.6: Drought indices

Indices	Input	Measures	Monitor	Reference
Palmer drought severity index (PDSI)	Precipitation and temperature	Moisture supply and demand within a two-layer soil model	Agricultural droughts	Palmer (1965)
Crop moisture index (CMI)	Precipitation and temperature	Short-term moisture conditions	Agricultural droughts	Palmer (1968)
Surface water supply index (SWSI)	Reservoir storage, streamflow, snowpack, and precipitation	Abnormalities in surface water supply sources	Hydrological drought	Shafer and Dezman (1982)
Standardized precipitation index (SPI)	Precipitation	Soil moisture at short timescales and groundwater and reservoir storage at longer timescales	Meteorological drought	McKee, Doesken, and Kleist (1993)
Soil moisture drought index (SMDI)	Soil moisture and evapotranspiration	Soil water in the root zone every week	Drought affecting agriculture	Hollinger, Isard, and Welford (1993)
Crop-specific drought index (CSDI)	Precipitation, temperature, solar radiation, available water substance, dew point temperature, crop data	The drought stress occurred during plant growth and estimates the overall impact on yield	The impact of drought on crop yields	Meyer and Hubbard (1995)
Vegetation condition index (VCI)	Advanced very high-resolution radiometer (AVHRR) radiance	Vegetation changes	Agricultural droughts	Liu and Kogan (1996)
Potential Evapotranspiration Deficit (PED)	Soil moisture and evapotranspiration	The difference between potentially lost water from soil to actual available water in the soil	Drought affecting agriculture	NIWA, (2007a)
New Zealand Drought Index (NZDI)	Precipitation, water in the soil, and evapotranspiration	Combined index based on the Standardised Precipitation Index (SPI), Soil Moisture Deficit (SMD), Soil Moisture Deficit Anomaly (SMDA), and Potential Evapotranspiration Deficit (PED)	Meteorological drought and drought affecting agriculture	NIWA, (2017)
New Zealand Pasture Growth Index (NZPGI)	Temperature, moisture, and sunlight	The amount of grass expected to grow in a "normal" hectare of farmland	Early warning of climate shocks and drought affecting agriculture	Stone et al. (2019)

Table 2.7: Set of Variables description and purpose

Variables	Description	Purpose
Capital structure 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)
Real total equity	(Total equity / GDP deflator) x 100	To examine the value of a business owned by farmers. (1.4)
Real total profit	(Total profit / GDP deflator) x 100	To identify farmers' profitability (1.5)
Real interest paid	(Total interest paid / GDP deflator) x 100	To identify the cost of debt (1.6)
Drought Measures (Independent Variables)		
All Drought	The NZPGI ≤ 30 for consecutively 10 or more days	To identify the mild and severe drought conditions
Mild Drought	The 20 ≤ NZPGI ≤ 30 for consecutively 10 to 20 days	To identify the mild drought conditions only
Severe drought	The NZPGI ≤ 20 for consecutively 20 or more days	To identify the severe drought conditions only
Consecutive drought season	The count of drought seasons in a row at each farm level	To identify the continuous drought seasons each year

Table 2.8: Descriptive Statistics by industry across farm sizes[7]

Variables	Dairy Farming				Sheep and Beef Farming			
	Observations	**No. of Farms**	**Mean**	**SD**	**Observations**	**No. of Farms**	**Mean**	**SD**
				Small Farms				
Real Short-term-Debt	8,775	873	177	439.11	15,939	1,248	52	262
Real Long-term-Debt	8,775	873	682	1,077	15,939	1,248	89	361
Real Total Debt	8,775	873	862	1,243	15,939	1,248	143	463
Real Total Equity	8,775	873	1,699	1,745	15,939	1,248	589	1,423
Real Total Profit	8,775	873	77	135	15,939	1,248	6	102
Real Interest Paid	8,775	873	48	76	15,939	1,248	5	20
Farmland	8,595	873	69.42	20.64	15,624	1,248	36.77	52.84
				Medium Farms				
Real Short-term-Debt	13,521	1,248	393	1,000	6,516	672	90	217
Real Long-term-Debt	13,521	1,248	1,618	2,872	6,516	672	218	479
Real Total Debt	13,521	1,248	2,028	3,237	6,516	672	319	891
Real Total Equity	13,521	1,248	2,633	6,093	6,516	672	1,493	5,533
Real Total Profit	13,521	1,248	98	254	6,516	672	48	293
Real Interest Paid	13,521	1,248	114	219	6,516	672	14	33
Farmland	13,275	1,248	167.73	53.4	6,420	672	185.31	78.44
				Large Farms				
Real Short-term-Debt	3,837	462	958	2,748	5,232	480	318	1,011
Real Long-term-Debt	3,837	462	4,6658	8,736	5,232	480	730	3,390
Real Total Debt	3,837	462	5,647	9,938	5,232	480	1,056	3,847
Real Total Equity	3,837	462	4,554	15,600	5,232	480	2,229	13,000
Real Total Profit	3,837	462	133	446	5,232	480	71	331
Real Interest Paid	3,837	462	307	502	5,232	480	49	181
Farmland	3795	462	497.71	267.96	5,193	480	1,059.11	2,821.14

Data Source: Statistics NZ

[7] All the values of Mean and SD are in NZD 000 except for the farmland size in ha

Table 2.9: Regression results for Real Short-term-Debt of Dairy Farming by sizes (NZD in 000)

Indicators	**Small Farm**		**Medium Farm**		**Large Farm**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	29.84***	30.36***	42.58***	44.11***	-12.91	-33.63
	(9.70)	(10.03)	(13.53)	(13.82)	(101.90)	(103.44)
Drought (t-1)	2.86	3.26	49.17***	50.54***	112.40	90.47
	(12.04)	(12.41)	(13.42)	(13.60)	(140.90)	(140.51)
Drought (t-2)	26.37**	26.79**	78.25***	79.44***	125.60	109.14
	(13.43)	(13.15)	(16.61)	(16.67)	(81.70)	(83.35)
Cons. Drought		1.03		2.30		-24.96*
		(2.74)		(3.95)		(15.04)
Obs	8,775	8,775	13,521	13,521	3,837	3,837
Adj R-Sq	0.3533	0.3533	0.5831	0.5831	0.3758	0.3761
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	30.02***	29.89***	41.42***	40.82***	-12.29	-36.74
	(10.28)	(10.78)	(13.49)	(13.74)	(107.88)	(110.12)
Drought (t-1)	4.84	4.69	48.68***	48.00***	129.11	100.42
	(13.08)	(13.94)	(13.84)	(14.11)	(150.69)	(151.28)
Drought (t-2)	30.30**	30.19**	76.08***	75.58***	116.52	97.00
	(14.59)	(14.12)	(17.62)	(17.65)	(83.98)	(86.86)
Cons. Drought		-0.24		-0.83		-27.14*
		(2.72)		(4.14)		(15.79)
Obs	7,989	7,989	12,486	12,486	3,630	3,630
Adj R-Sq	0.3347	0.3346	0.5246	0.5245	0.3601	0.3605
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	24.96	25.09	39.05	35.09	46.24	58.46
	(16.73)	(16.82)	(32.47)	(32.14)	(177.67)	(177.98)
Drought (t-1)	8.10	7.78	66.07***	75.39***	194.16	139.24
	(15.99)	(17.85)	(18.23)	(20.04)	(224.25)	(233.85)
Drought (t-2)	52.03***	51.80***	107.78***	114.21***	59.23	24.34
	(15.51)	(15.23)	(22.86)	(23.32)	(153.97)	(169.47)
Cons. Drought		-0.15		4.16		-20.72
		(2.88)		(4.11)		(15.62)
Obs	5,601	5,601	8,862	8,862	2,517	2,517
Adj R-Sq	0.3787	0.3785	0.5847	0.5848	0.3784	0.3784

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

Table 2.10: Regression results for Real Long-term-Debt of Dairy Farming by sizes (NZD in 000)

Indicators	**Small Farm**		**Medium Farm**		**Large Farm**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	12.39 (14.96)	16.72 (14.96)	18.18 (37.28)	24.97 (36.60)	117.16 (124.10)	147.32 (131.20)
Drought (t-1)	31.77** (15.55)	35.13** (15.58)	69.78* (40.29)	75.88* (40.13)	26.29 (120.62)	58.20 (129.22)
Drought (t-2)	25.83 (16.89)	29.31* (16.83)	119.75** (50.41)	125.04** (50.32)	183.76 (147.12)	207.73 (150.78)
Cons. Drought		8.51* (4.42)		10.25* (6.02)		36.32 (28.52)
Obs	8,775	8,775	13,521	13,521	3,837	3,837
Adj R-Sq	0.7852	0.7856	0.7311	0.7311	0.8251	0.8252
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	9.60 (15.12)	13.46 (15.19)	7.61 (41.10)	15.83 (40.40)	73.50 (129.67)	104.21 (136.77)
Drought (t-1)	26.28 (16.45)	30.80* (16.70)	66.40 (41.67)	75.74* (41.53)	62.06 (135.50)	98.10 (146.21)
Drought (t-2)	20.61 (17.63)	24.09 (17.51)	125.53** (58.84)	132.52** (58.62)	104.48 (166.76)	129.00 (170.35)
Cons. Drought		7.19 (4.77)		11.39* (6.02)		34.09 (29.49)
Obs	7,989	7,989	12,486	12,486	3,630	3,630
Adj R-Sq	0.7876	0.7878	0.7219	0.722	0.822	0.8221
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	46.84 (31.03)	36.92 (30.88)	96.33 (58.45)	75.98 (57.79)	597.55 (462.41)	560.90 (468.09)
Drought (t-1)	42.96** (21.69)	66.13** (25.75)	110.12*** (33.34)	158.03*** (37.49)	85.28 (146.99)	249.99 (193.29)
Drought (t-2)	42.87* (23.85)	59.64** (25.54)	166.20*** (56.68)	199.30*** (58.87)	274.93* (155.98)	379.57** (179.35)
Cons. Drought		11.05* (5.66)		21.42*** (6.52)		62.13 (41.66)
Obs	5,601	5,601	8,862	8,862	2,517	2,517
Adj R-Sq	0.7636	0.7643	0.7999	0.8003	0.8457	0.8459

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

Table 2.11: Regression results for Real Total Debt of Dairy Farming by sizes (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	36.17** (16.97)	41.03** (16.95)	49.26 (40.71)	57.22 (40.05)	66.67 (135.48)	75.76 (143.86)
Drought (t-1)	26.31 (16.39)	30.08* (16.52)	107.02** (42.55)	114.18*** (42.35)	151.71 (164.51)	161.33 (170.73)
Drought (t-2)	55.42*** (19.73)	59.32*** (19.62)	186.12*** (52.22)	192.32*** (52.15)	317.47* (161.39)	324.70* (165.78)
Cons. Drought		9.54** (4.84)		12.03* (6.36)		10.95 (31.36)
Obs	8,775	8,775	13,521	13,521	3,837	3,837
Adj R-Sq	0.8049	0.8053	0.7579	0.758	0.8165	0.8165
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	32.87* (17.25)	36.67** (17.14)	37.74 (44.34)	45.10 (43.63)	31.76 (145.51)	37.55 (153.71)
Drought (t-1)	22.88 (17.37)	27.34 (17.62)	102.58** (43.91)	110.94** (43.68)	209.70 (186.43)	216.49 (194.45)
Drought (t-2)	57.43*** (21.60)	60.86*** (21.44)	189.38*** (60.17)	195.64*** (59.92)	225.17 (184.62)	229.79 (189.34)
Cons. Drought		7.09 (5.01)		10.20 (6.54)		6.42 (32.41)
Obs	7,989	7,989	12,486	12,486	3,630	3,630
Adj R-Sq	0.7994	0.7996	0.7462	0.7463	0.8149	0.8148
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	67.98** (29.20)	58.88** (29.25)	128.15** (64.43)	106.55* (63.53)	516.64 (580.73)	489.46 (587.74)
Drought (t-1)	38.81* (23.05)	60.08** (26.75)	155.61*** (38.19)	206.46*** (43.09)	286.50 (227.62)	408.69 (259.89)
Drought (t-2)	82.50*** (26.04)	97.90*** (26.65)	254.66*** (61.47)	289.79*** (63.86)	367.99* (210.22)	445.61* (239.80)
Cons. Drought		10.15* (5.99)		22.73*** (7.85)		46.09 (43.64)
Obs	5,601	5,601	8,862	8,862	2,517	2,517
Adj R-Sq	0.8004	0.8009	0.8086	0.8089	0.8344	0.8345

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

Table 2.12: Regression results for Real Short-term-Debt of Sheep/Beef Farming by sizes (NZD in 000)

Indicators	**Small Farm**		**Medium Farm**		**Large Farm**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	7.75*	7.61*	2.38	2.88	44.08**	47.93***
	(4.08)	(3.97)	(4.54)	(5.03)	(17.90)	(18.07)
Drought (t-1)	3.84	3.71	2.06	2.56	62.82**	66.26**
	(4.73)	(4.75)	(4.57)	(5.03)	(28.40)	(29.06)
Drought (t-2)	5.94	5.85	8.83*	9.20*	46.70*	48.73*
	(5.78)	(5.78)	(4.83)	(5.04)	(25.13)	(25.20)
Cons. Drought		-0.32		0.66		7.75**
		(1.06)		(2.86)		(3.90)
Obs	15,939	15,939	6,516	6,516	5,232	5,232
Adj R-Sq	0.388	0.3879	0.408	0.408	0.5913	0.5917
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	7.79*	7.55*	1.27	1.88	36.72	41.03*
	(4.29)	(4.17)	(4.17)	(4.88)	(22.29)	(22.48)
Drought (t-1)	5.96	5.64	-0.29	0.42	63.64**	69.06**
	(4.79)	(4.86)	(4.14)	(5.04)	(26.22)	(27.72)
Drought (t-2)	5.73	5.54	7.94*	8.43*	60.06***	63.65***
	(6.27)	(6.28)	(4.69)	(5.02)	(22.83)	(23.57)
Cons. Drought		-0.52		0.75		7.29*
		(1.06)		(3.20)		(4.26)
Obs	14,757	14,757	6,105	6,105	4,695	4,695
Adj R-Sq	0.3773	0.3773	0.4178	0.4177	0.5005	0.5008
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	8.24	8.34	10.34	6.67	100.38**	101.62**
	(5.57)	(5.85)	(22.03)	(22.48)	(40.03)	(40.47)
Drought (t-1)	3.86	3.68	7.38	15.63	18.16	16.56
	(5.14)	(5.96)	(6.11)	(12.82)	(22.54)	(24.26)
Drought (t-2)	6.10	5.98	10.27	15.63	47.93**	46.95*
	(5.59)	(5.67)	(6.75)	(10.08)	(23.68)	(23.97)
Cons. Drought		-0.09		3.65		-0.73
		(1.35)		(5.03)		(3.22)
Obs	9,846	9,846	4,191	4,191	3,204	3,204
Adj R-Sq	0.4263	0.4263	0.3245	0.3255	0.8013	0.8012

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

Table 2.13: Regression results for Real Long-term-Debt of Sheep/Beef Farming by sizes (NZD in 000)

Indicators	**Small Farm**		**Medium Farm**		**Large Farm**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	-1.73 (3.21)	-0.65 (3.36)	6.73 (7.21)	5.51 (8.27)	6.61 (23.45)	21.18 (23.53)
Drought (t-1)	0.65 (4.57)	1.63 (4.71)	2.91 (6.33)	1.70 (6.92)	-7.46 (30.31)	5.56 (29.26)
Drought (t-2)	-1.79 (6.32)	-1.08 (6.45)	1.48 (6.29)	0.56 (6.50)	-5.71 (24.82)	1.98 (23.88)
Cons. Drought		2.50** (1.06)		-1.61 (3.75)		29.38** (14.35)
Obs	15,939	15,939	6,516	6,516	5,232	5,232
Adj R-Sq	0.7923	0.7925	0.7561	0.7561	0.9084	0.9089
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	-2.07 (3.16)	-0.81 (3.34)	7.37 (7.39)	6.76 (8.41)	-1.15 (25.51)	15.63 (24.93)
Drought (t-1)	-0.50 (4.81)	1.10 (5.08)	3.67 (6.20)	2.97 (6.87)	-11.33 (31.55)	9.76 (29.16)
Drought (t-2)	-2.37 (6.27)	-1.39 (6.46)	2.52 (6.95)	2.03 (7.17)	-9.01 (26.41)	4.95 (24.33)
Cons. Drought		2.67** (1.19)		-0.75 (3.64)		28.35** (13.19)
Obs	14,757	14,757	6,105	6,105	4,695	4,695
Adj R-Sq	0.7522	0.7525	0.7435	0.7434	0.9175	0.9179
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	3.62 (10.56)	2.18 (10.36)	5.74 (24.03)	11.68 (24.09)	62.94 (59.44)	-3.92 (64.33)
Drought (t-1)	-6.23 (4.85)	-3.42 (5.06)	-0.60 (7.99)	-13.99 (14.88)	-16.09 (35.21)	70.10* (36.77)
Drought (t-2)	-4.05 (6.43)	-2.24 (6.65)	9.42 (9.31)	0.71 (12.38)	-46.10 (32.07)	6.83 (28.91)
Cons. Drought		1.37 (1.09)		-5.93 (5.58)		39.49** (17.16)
Obs	9,846	9,846	4,191	4,191	3,204	3,204
Adj R-Sq	0.8082	0.8082	0.7399	0.7405	0.5094	0..5136

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

Table 2.14: Regression results for Real Total Debt of Sheep/Beef Farming by sizes (NZD in 000)

Indicators	**Small Farm**		**Medium Farm**		**Large Farm**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	2.99	3.90	-14.75	-15.18	57.38**	75.99***
	(4.76)	(4.75)	(24.56)	(24.79)	(28.17)	(27.83)
Drought (t-1)	2.06	2.90	-20.23	-20.66	58.34	74.96*
	(6.12)	(6.23)	(25.59)	(25.64)	(41.01)	(40.25)
Drought (t-2)	2.23	2.83	-15.93	-16.26	44.77	54.59
	(8.15)	(8.23)	(24.21)	(24.17)	(36.79)	(36.08)
Cons. Drought		2.12		-0.57		37.51***
		(1.35)		(5.38)		(14.26)
Obs	15,939	15,939	6,516	6,516	5,232	5,232
Adj R-Sq	0.7037	0.7038	0.3621	0.362	0.9105	0.9111
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	2.89	3.85	-16.51	-16.34	44.05	65.76**
	(4.76)	(4.73)	(26.08)	(26.51)	(32.94)	(32.06)
Drought (t-1)	2.79	4.01	-22.06	-21.86	55.46	82.75**
	(6.49)	(6.75)	(26.78)	(27.12)	(40.83)	(39.39)
Drought (t-2)	0.91	1.65	-17.42	-17.28	55.84	73.91**
	(8.36)	(8.47)	(25.74)	(25.87)	(36.33)	(34.98)
Cons. Drought		2.03		0.21		36.69***
		(1.45)		(5.55)		(13.68)
Obs	14,757	14,757	6,105	6,105	4,695	4,695
Adj R-Sq	0.6659	0.666	0.3308	0.3307	0.9181	0.9187
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	7.15	5.70	23.01	29.43	157.60**	92.50
	(12.30)	(12.23)	(25.57)	(28.87)	(70.12)	(75.89)
Drought (t-1)	-3.84	-1.01	-25.91	-40.37	5.44	89.36**
	(7.04)	(7.77)	(33.34)	(47.03)	(38.13)	(40.44)
Drought (t-2)	0.34	2.16	-45.40	-54.81	-2.50	49.04
	(8.69)	(8.87)	(64.71)	(72.01)	(40.75)	(39.14)
Cons. Drought		1.38		-6.40		38.45**
		(1.48)		(9.80)		(17.93)
Obs	9,846	9,846	4,191	4,191	3,204	3,204
Adj R-Sq	0.7366	0.7366	0.359	0.359	0.667	0.6694

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

Table 2.15: Regression results for Real Total Equity of Dairy Farming by sizes (NZD in 000)

Indicators	**Small Farm**		**Medium Farm**		**Large Farm**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	167.41***	181.07***	126.08*	140.67*	87.89	79.00
	(37.04)	(37.20)	(74.07)	(75.59)	(136.92)	(144.90)
Drought (t-1)	190.51***	201.09***	239.60*	252.72*	-159.82	-169.23
	(33.76)	(33.48)	(137.82)	(136.55)	(139.82)	(149.03)
Drought (t-2)	150.71***	161.68***	163.18**	174.56*	-132.39	-139.46
	(34.11)	(33.83)	(77.55)	(78.74)	(135.29)	(142.23)
Cons. Drought		26.81***		22.03**		-10.71
		(7.65)		(10.31)		(26.36)
Obs	8,775	8,775	13,521	13,521	3,837	3,837
Adj R-Sq	0.6511	0.6528	0.5245	0.5245	0.9485	0.9485
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	150.03***	162.09***	120.53	139.10*	87.78	86.20
	(37.36)	(37.40)	(77.44)	(78.97)	(131.73)	(140.40)
Drought (t-1)	203.74***	217.87***	285.41*	306.51**	-55.59	-57.43
	(36.53)	(35.94)	(149.52)	(147.89)	(140.29)	(149.21)
Drought (t-2)	162.45***	173.34***	177.66**	193.44**	-231.13	-232.38
	(36.75)	(36.28)	(87.61)	(88.95)	(160.24)	(168.80)
Cons. Drought		22.49***		25.71**		-1.75
		(7.11)		(10.49)		(26.51)
Obs	7,989	7,989	12,486	12,486	3,630	3,630
Adj R-Sq	0.6465	0.6476	0.5064	0.5065	0.952	0.952
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	287.35***	256.82***	218.61**	179.62**	-112.44	-139.57
	(82.69)	(82.79)	(90.19)	(90.75)	(586.14)	(590.50)
Drought (t-1)	131.41***	202.71***	263.42	355.20*	3.68	125.60
	(41.51)	(43.32)	(193.94)	(195.50)	(172.86)	(196.14)
Drought (t-2)	251.70***	303.32***	282.95***	346.36***	58.75	136.20
	(46.54)	(47.26)	(86.52)	(86.79)	(247.96)	(272.49)
Cons. Drought		34.02***		41.03***		45.99
		(7.48)		(11.53)		(30.98)
Obs	5,601	5,601	8,862	8,862	2,517	2,517
Adj R-Sq	0.6262	0.6288	0.382	0.3822	0.9641	0.9641

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

Table 2.16: Regression results for Real Total Profit of Dairy Farming by sizes (NZD in 000)

Indicators	**Small Farm**		**Medium Farm**		**Large Farm**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	-7.52**	-8.10**	-19.30***	-20.91***	-59.98***	-61.47***
	(3.24)	(3.24)	(4.79)	(4.78)	(16.96)	(17.30)
Drought (t-1)	-5.57*	-6.02**	-11.03***	-12.48***	-3.05	-4.63
	(2.92)	(2.93)	(3.72)	(3.73)	(17.75)	(18.08)
Drought (t-2)	-15.26***	-15.73***	-37.74***	-39.00***	-57.55***	-58.74***
	(3.83)	(3.85)	(5.09)	(5.09)	(17.73)	(18.06)
Cons. Drought		-1.14**		-2.43***		-1.80
		(0.48)		(0.71)		(2.75)
Obs	8,775	8,775	13,521	13,521	3,837	3,837
Adj R-Sq	0.321	0.3214	0.3505	0.3511	0.1576	0.1574
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	-11.28***	-12.01***	-21.16***	-23.33***	-57.84***	-58.28***
	(3.21)	(3.21)	(5.31)	(5.30)	(17.41)	(17.81)
Drought (t-1)	-9.34***	-10.20***	-10.55***	-13.03***	7.66	7.15
	(2.99)	(3.02)	(3.95)	(3.97)	(18.40)	(18.87)
Drought (t-2)	-9.65**	-10.31***	-33.01***	-34.86***	-59.81***	-60.17***
	(3.75)	(3.77)	(5.12)	(5.11)	(19.28)	(19.69)
Cons. Drought		-1.36***		-3.02***		-0.49
		(0.44)		(0.62)		(2.88)
Obs	7,989	7,989	12,486	12,486	3,630	3,630
Adj R-Sq	0.3339	0.3345	0.3855	0.3865	0.1511	0.1508
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	9.99	10.94	-17.57**	-15.51*	-114.84***	-111.77**
	(10.88)	(10.89)	(8.41)	(10.04)	(43.91)	(43.63)
Drought (t-1)	-14.87***	-17.09***	-20.91***	-25.76***	-27.91	-41.69*
	(5.44)	(5.61)	(6.49)	(6.91)	(23.47)	(24.69)
Drought (t-2)	-14.09**	-15.69***	-33.28***	-36.63***	-45.78*	-54.54**
	(5.51)	(5.69)	(6.35)	(6.52)	(24.85)	(26.52)
Cons. Drought		-1.06		-2.17**		-5.20
		(0.65)		(0.88)		(3.61)
Obs	5,601	5,601	8,862	8,862	2,517	2,517
Adj R-Sq	0.2922	0.2924	0.384	0.3844	0.1553	0.1557

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

Table 2.17: Regression results for Real Total Interest of Dairy Farming by sizes (NZD in 000)

Indicators	**Small Farm**		**Medium Farm**		**Large Farm**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	2.49**	2.85***	3.01	3.91	4.42	6.68
	(0.97)	(0.97)	(3.43)	(3.36)	(7.06)	(7.35)
Drought (t-1)	1.63*	1.92**	-1.70	-0.90	-3.70	-1.30
	(0.95)	(0.95)	(4.65)	(4.68)	(10.45)	(1.05)
Drought (t-2)	-0.78	-0.49	10.24**	10.94**	-0.24	-1.56
	(0.93)	(0.93)	(4.93)	(4.90)	(11.59)	(11.59)
Cons. Drought		0.70**		1.36***		2.73*
		(0.31)		(0.44)		(1.62)
Obs	8,775	8,775	13,521	13,521	3,837	3,837
Adj R-Sq	0.7381	0.7387	0.6141	0.6143	0.8113	0.8115
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	2.38**	2.83***	2.78	3.87	4.20	6.65
	(0.99)	(1.00)	(3.67)	(3.58)	(6.81)	(7.16)
Drought (t-1)	1.38	1.90*	-2.93	-1.70	-1.33	1.55
	(1.04)	(1.06)	(5.09)	(5.14)	(10.12)	(10.30)
Drought (t-2)	-0.86	-0.45	11.59**	12.51**	-3.64	-1.68
	(0.99)	(1.00)	(5.55)	(5.51)	(12.79)	(12.86)
Cons. Drought		0.83**		1.50***		2.73
		(0.33)		(0.48)		(1.68)
Obs	7,989	7,989	12,486	12,486	3,630	3,630
Adj R-Sq	0.7308	0.7315	0.6017	0.602	0.8086	0.8087
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	4.67***	3.96**	5.52	3.73	11.50	9.45
	(1.73)	(1.74)	(3.71)	(3.69)	(29.19)	(29.71)
Drought (t-1)	2.66**	4.31***	3.81*	8.04***	-4.62	4.59
	(1.29)	(1.56)	(2.27)	(2.58)	(17.91)	(19.97)
Drought (t-2)	-1.33	-0.13	7.03*	9.95***	5.33	11.18
	(1.30)	(1.42)	(3.58)	(3.71)	(12.15)	(13.53)
Cons. Drought		0.79*		1.89***		3.48
		(0.43)		(0.56)		(2.32)
Obs	5,601	5,601	8,862	8,862	2,517	2,517
Adj R-Sq	0.6937	0.6944	0.802	0.8026	0.8026	0.8028

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

Table 2.18: Regression results for Real Total Equity of Sheep/Beef Farming by sizes (NZD in 000)

Indicators	**Small Farm**		**Medium Farm**		**Large Farm**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	10.53 (15.04)	11.38 (14.49)	17.78 (33.35)	46.93 (36.04)	119.44 (159.66)	121.33 (156.77)
Drought (t-1)	-20.70 (31.93)	-19.92 (32.70)	43.08 (67.05)	72.02 (70.75)	49.85 (68.83)	51.54 (69.93)
Drought (t-2)	48.75*** (18.15)	49.31*** (17.68)	140.94* (74.99)	162.82** (77.51)	19.89 (47.17)	20.88 (47.45)
Cons. Drought		1.97 (3.48)		38.49*** (12.70)		3.80 (19.76)
Obs	15,939	15,939	6,516	6,516	5,232	5,232
Adj R-Sq	0.3127	0.3127	0.8402	0.8404	0.9651	0.9651
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	11.65 (15.93)	11.86 (15.18)	21.09 (35.73)	53.25 (39.72)	112.00 (168.76)	115.03 (164.30)
Drought (t-1)	-23.07 (34.54)	-22.81 (35.98)	44.12 (70.60)	81.35 (76.66)	60.74 (71.39)	64.55 (73.57)
Drought (t-2)	51.99-*** (19.86)	52.14*** (19.09)	150.23* (79.60)	176.11** (83.48)	40.36 (48.03)	42.89 (49.09)
Cons. Drought		0.43 (3.56)		39.70*** (14.19)		5.13 (19.14)
Obs	14,757	14,757	6,105	6,105	4,695	4,695
Adj R-Sq	0.2862	0.2861	0.8396	0.8398	0.9668	0.9667
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	-8.21 (14.63)	-17.79 (15.39)	-36.28 (68.26)	-109.42 (77.13)	-63.68 (127.90)	-101.47 (126.12)
Drought (t-1)	25.88** (12.63)	44.54*** (15.34)	98.73 (117.07)	263.35 (165.50)	84.31 (77.67)	133.02 (85.60)
Drought (t-2)	46.79*** (14.40)	58.79*** (15.77)	122.13* (69.97)	229.24** (100.74)	18.62 (64.84)	48.54 (65.26)
Cons. Drought		9.11** (3.71)		72.87*** (27.59)		22.32 (17.31)
Obs	9,846	9,846	4,191	4,191	3,204	3,204
Adj R-Sq	0.7105	0.711	0.8072	0.8077	0.9224	0.9225

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

Table 2.19: Regression results for Real Total Profit of Sheep/Beef Farming by sizes (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	-4.42*	-4.57	7.53	7.46	12.43	11.99
	(2.32)	(2.40)	(10.44)	(10.13)	(16.89)	(16.40)
Drought (t-1)	0.04	-0.09	5.70	5.64	0.88	0.49
	(1.73)	(1.66)	(4.83)	(4.58)	(5.38)	(5.26)
Drought (t-2)	1.73	1.63	8.01	7.96	-10.52	-10.75
	(1.92)	(1.86)	(8.54)	(8.30)	(7.05)	(7.10)
Cons. Drought		-0.35		-0.08		0.89
		(0.36)		(0.92)		(1.60)
Obs	15,939	15,939	6,516	6,516	5,232	5,232
Adj R-Sq	0.1275	0.1275	0.1687	0.1685	0.1827	0.1826
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	-4.29*	-4.43*	8.69	8.59	16.95	15.91
	(2.39)	(2.47)	(11.09)	(10.77)	(17.98)	(17.26)
Drought (t-1)	0.01	-0.16	5.69	5.57	5.50	4.19
	(1.83)	(1.73)	(5.04)	(4.77)	(6.44)	(6.45)
Drought (t-2)	1.67	1.57	8.09	8.01	-4.31	-5.17
	(2.00)	(1.92)	(9.20)	(8.94)	(4.20)	(4.33)
Cons. Drought		-0.29		-0.13		-1.76
		(0.39)		(0.99)		(1.66)
Obs	14,757	14,757	6,105	6,105	4,695	4,695
Adj R-Sq	0.1159	0.1158	0.162	0.1618	0.2588	0.2588
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	-5.06**	-4.98**	-11.60**	-12.89**	-42.54***	-44.47***
	(2.40)	(2.36)	(5.58)	(5.60)	(15.84)	(15.51)
Drought (t-1)	3.44	3.26	13.20	16.10	5.96	8.44
	(4.93)	(4.97)	(13.85)	(14.98)	(8.12)	(9.10)
Drought (t-2)	2.35	2.24	-6.33	-4.44	-15.57	-14.04
	(2.67)	(2.69)	(6.79)	(6.58)	(13.70)	(15.24)
Cons. Drought		-0.08		1.28		1.14
		(0.38)		(1.39)		(2.04)
Obs	9,846	9,846	4,191	4,191	3,204	3,204
Adj R-Sq	0.1404	0.1403	0.1081	0.108	0.0718	0.0716

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

Table 2.20: Regression results for Real Total Interest of Sheep/Beef Farming by sizes (NZD in 000)

Indicators	**Small Farm**		**Medium Farm**		**Large Farm**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	0.07 (0.21)	0.12 (0.22)	0.13 (0.54)	-0.22 (0.71)	0.74 (1.10)	1.18 (1.16)
Drought (t-1)	0.01 (0.23)	0.05 (0.24)	-0.33 (0.49)	-0.67 (0.65)	-0.40 (1.33)	-0.001 (1.37)
Drought (t-2)	-0.14 (0.22)	-0.11 (0.22)	-0.97** (0.46)	-1.24** (0.57)	0.93 (1.26)	1.17 (1.28)
Cons. Drought		0.11* (0.06)		-0.46 (0.52)		0.89 (0.67)
Obs	15,939	15,939	6,516	6,516	5,232	5,232
Adj R-Sq	0.8175	0.8176	0.6526	0.6534	0.893	0.8931
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	0.04 (0.21)	0.09 (0.22)	0.23 (0.57)	-0.11 (0.78)	0.47 (1.15)	1.07 (1.20)
Drought (t-1)	-0.14 (0.22)	-0.08 (0.23)	-0.37 (0.43)	-0.77 (0.71)	-0.63 (1.37)	0.12 (1.41)
Drought (t-2)	-0.14 (0.22)	-0.10 (0.22)	-0.83* (0.44)	-1.11* (0.59)	0.67 (1.27)	1.17 (1.29)
Cons. Drought		0.10 (0.05)		-0.43 (0.58)		1.01** (0.39)
Obs	14,757	14,757	6,105	6,105	4,695	4,695
Adj R-Sq	0.7857	0.7859	0.6301	0.6308	0.9087	0.9088
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	0.55 (0.62)	0.43 (0.59)	-0.24 (1.23)	0.76 (1.54)	5.10* (2.86)	3.14 (3.04)
Drought (t-1)	-0.22 (0.29)	0.01 (0.34)	-0.94* (0.55)	-3.19 (2.19)	-0.69 (1.47)	1.84 (1.90)
Drought (t-2)	0.01 (0.27)	0.16 (0.27)	-0.29 (0.57)	-1.75 (1.50)	-0.35 (1.78)	1.21 (1.98)
Cons. Drought		0.12 (0.07)		-0.99 (0.92)		1.16 (0.65)
Obs	9,846	9,846	4,191	4,191	3,204	3,204
Adj R-Sq	0.8187	0.8188	0.5931	0.597	0.7586	0.7595

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

Table 2.21: Regression results for Debt of Dairy Farming using PED as drought indicator (NZD in 000)

Indicators	Real Short-term-Debt		Real Long-term-Debt		Real Total Debt	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (Cumulative PED ≥250mm)						
Drought (t)	14.84 (14.61)	30.13* (16.21)	132.54*** (39.70)	181.46*** (42.13)	145.75*** (43.31)	206.57*** (46.18)
Drought (t-1)	36.52** (16.36)	52.72*** (17.85)	127.64*** (48.31)	179.48*** (50.50)	163.72*** (54.85)	228.17*** (57.55)
Drought (t-2)	45.95*** (15.89)	58.15*** (16.76)	138.18** (64.09)	177.24*** (65.35)	180.22*** (68.79)	228.78*** (70.33)
Cons. Drought		17.24*** (4.94)		55.17*** (10.72)		68.59*** (11.36)
Obs	26,142	26,142	26,142	26,142	26,142	26,142
Adj R-Sq	0.4333	0.4348	0.7812	0.7829	0.791	0.793
Mild Droughts (Cumulative PED≤320mm and Cumulative PED>250mm) excluding severe drought						
Drought (t)	8.56 (17.75)	24.62 (19.16)	116.49** (45.00)	170.63*** (47.82)	124.30** (50.35)	190.75*** (53.68)
Drought (t-1)	33.35** (16.71)	54.35*** (18.54)	121.50** (52.64)	192.31*** (56.32)	154.41** (60.19)	241.30*** (64.54)
Drought (t-2)	53.60*** (16.78)	68.64*** (17.82)	129.12** (60.78)	179.84*** (62.63)	179.51*** (66.08)	241.75*** (68.36)
Cons. Drought		16.80*** (4.98)		56.65*** (11.19)		69.52*** (11.87)
Obs	24,462	24,462	24,462	24,462	24,462	24,462
Adj R-Sq	0.3982	0.3998	0.7825	0.7842	0.7902	0.7922
Severe Droughts (Cumulative PED > 320mm) excluding mild drought						
Drought (t)	48.51** (24.15)	53.03** (24.29)	208.84*** (60.16)	224.09*** (60.61)	249.59*** (62.91)	268.43*** (62.28)
Drought (t-1)	59.42*** (18.93)	95.85*** (23.40)	155.56*** (51.97)	278.62*** (58.68)	217.71*** (53.89)	369.74*** (61.54)
Drought (t-2)	46.90** (18.24)	71.10*** (20.18)	172.07** (71.60)	253.83*** (74.33)	214.19*** (75.19)	315.19*** (78.16)
Cons. Drought		18.53*** (5.52)		62.60*** (11.82)		77.34*** (12.52)
Obs	20,892	20,892	20,892	20,892	20,892	20,892
Adj R-Sq	0.4232	0.4232	0.7605	0.7632	0.7738	0.7769

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

Table 2.22: Regression results for Debt of sheep/beef Farming using PED as drought indicator (NZD in 000)

Indicators	**Real Short-term-Debt**		**Real Long-term-Debt**		**Real Total Debt**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (Cumulative PED ≥250mm)						
Drought (t)	3.16	10.95	27.36	31.24	28.66	39.42*
	(6.42)	(6.86)	(19.30)	(19.56)	(20.88)	(21.26)
Drought (t-1)	2.00	9.70	21.79	25.63	22.33	32.98
	(5.61)	(5.97)	(20.63)	(20.91)	(21.41)	(21.74)
Drought (t-2)	1.15	7.67	-3.54	-0.29	-8.50	0.52
	(6.67)	(6.91)	(9.88)	(9.85)	(11.67)	(11.73)
Cons. Drought		4.59***		2.29		6.35***
		(1.06)		(1.51)		(1.76)
Obs	27,690	27,690	27,690	27,690	27,690	27,690
Adj R-Sq	0.5646	0.5657	0.9035	0.9035	0.8697	0.8699
Mild Droughts (Cumulative PED≤320mm and Cumulative PED>250mm) excluding severe drought						
Drought (t)	2.37	10.54	27.87	31.99	28.67	39.98*
	(6.93)	(7.38)	(20.37)	(20.68)	(22.11)	(22.54)
Drought (t-1)	3.66	12.31**	21.62	25.98	23.24	35.23
	(5.54)	(5.95)	(21.41)	(21.76)	(22.16)	(22.58)
Drought (t-2)	1.75	8.97	-1.97	1.66	-6.71	3.29
	(6.60)	(6.89)	(10.00)	(9.99)	(11.53)	(11.63)
Cons. Drought		4.68***		2.36		6.49***
		(1.07)		(1.52)		(1.77)
Obs	27,138	27,138	27,138	27,138	27,138	27,138
Adj R-Sq	0.565	0.5663	0.9047	0.9047	0.8704	0.8706
Severe Droughts (Cumulative PED > 320mm) excluding mild drought						
Drought (t)	9.74	13.94	20.39	22.36	27.54	33.17*
	(9.32)	(9.34)	(15.68)	(15.73)	(17.31)	(17.37)
Drought (t-1)	2.11	16.17**	8.52	15.13	9.07	27.96*
	(7.36)	(8.18)	(12.50)	(13.14)	(15.22)	(16.22)
Drought (t-2)	2.79	13.25	-1.05	3.87	-6.58	7.46
	(8.19)	(8.59)	(10.57)	(10.75)	(12.48)	(12.86)
Cons. Drought		4.95***		2.33		6.65***
		(1.13)		(1.57)		(1.85)
Obs	24,378	24,378	24,378	24,378	24,378	24,378
Adj R-Sq	0.5712	0.5726	0.9345	0.9346	0.8916	0.8918

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

Table 2.23: Regression results for Non-Debt of Dairy Farming using PED as drought indicator (NZD in 000)

Indicators	**Real Total Equity**		**Real Total Profit**		**Real Interest Paid**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (Cumulative PED ≥250mm)						
Drought (t)	263.64*** (52.67)	329.54*** (53.45)	-56.82*** (4.65)	-56.71*** (4.78)	13.98*** (3.56)	15.91*** (3.65)
Drought (t-1)	235.49*** (52.92)	305.32*** (53.79)	0.49 (3.64)	0.61 (3.77)	6.46* (3.33)	8.50** (3.44)
Drought (t-2)	114.39 (200.01)	167.01 (102.60)	8.03** (3.73)	8.12** (3.85)	5.99* (3.42)	7.53** (3.48)
Cons. Drought		74.32*** (10.25)		0.13 (0.69)		2.17*** (0.63)
Obs	26,142	26,142	26,142	26,142	26,142	26,142
Adj R-Sq	0.8008	0.8017	0.256	0.2559	0.7368	0.7374
Mild Droughts (Cumulative PED≤320mm and Cumulative PED>250mm) excluding severe drought						
Drought (t)	258.34*** (55.04)	334.56*** (57.00)	-44.26*** (4.52)	-44.20*** (4.61)	10.55*** (2.83)	12.68*** (2.98)
Drought (t-1)	209.47*** (52.53)	309.14*** (55.69)	1.63 (3.78)	1.72 (3.92)	8.02*** (2.85)	10.80*** (3.08)
Drought (t-2)	204.32*** (46.79)	275.72*** (48.56)	8.73** (3.62)	8.79** (3.72)	3.45 (2.52)	5.44** (2.64)
Cons. Drought		79.74*** (9.99)		0.07 (0.68)		2.22 (0.66)
Obs	24,462	24,462	24,462	24,462	24,462	24,462
Adj R-Sq	0.9188	0.92	0.2753	0.2752	0.7797	0.7804
Severe Droughts (Cumulative PED > 320mm) excluding mild drought						
Drought (t)	366.67** (171.89)	387.46** (170.73)	-99.65*** (8.28)	-99.50*** (8.31)	25.16*** (8.83)	25.71*** (8.82)
Drought (t-1)	242.14*** (48.47)	409.90*** (50.67)	6.09 (3.97)	7.26* (4.31)	4.92 (3.57)	9.37** (3.96)
Drought (t-2)	167.09 (117.12)	278.55** (122.06)	10.79** (4.21)	11.57*** (4.44)	8.49* (4.53)	11.45** (4.60)
Cons. Drought		85.34*** (11.05)		0.60 (0.76)		2.26*** (0.71)
Obs	20,892	20,892	20,892	20,892	20,892	20,892
Adj R-Sq	0.8007	0.802	0.2697	0.2698	0.6947	0.6955

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

Table 2.24: Regression results for non-Debt of sheep/beef Farming using PED as drought indicator (NZD in 000)

Indicators	Real Total Equity		Real Total Profit		Real Interest Paid	
Model	(1)	(2)	(1)	(2)	(1)	(2)
All Droughts (Cumulative PED ≥250mm)						
Drought (t)	43.65 (52.67)	80.31 (53.18)	-6.40* (3.51)	-5.62 (3.53)	0.43 (0.57)	0.32 (0.57)
Drought (t-1)	61.57 (82.76)	97.84 (83.23)	9.15 (8.59)	9.93 (8.58)	0.07 (0.53)	-0.03 (0.54)
Drought (t-2)	50.07 (49.21)	80.78 (49.50)	4.90* (2.73)	5.56** (2.73)	-0.04 (0.53)	-0.13 (0.52)
Cons. Drought		21.63*** (3.68)		0.46** (0.22)		-0.06 (0.08)
Obs	27,690	27,690	27,690	27,690	27,690	27,690
Adj R-Sq	0.901	0.9011	0.2026	0.2027	0.8852	0.8852
Mild Droughts (Cumulative PED≤320mm and Cumulative PED>250mm) excluding severe drought						
Drought (t)	26.91 (35.04)	64.38* (35.68)	-5.67* (3.19)	-4.83 (3.18)	0.39 (0.61)	0.28 (0.61)
Drought (t-1)	70.34 (95.31)	110.05 (95.71)	9.29 (8.82)	10.19 (8.84)	0.10 (0.55)	-0.02 (0.56)
Drought (t-2)	29.64 (33.55)	62.74* (33.95)	5.81 (2.30)	6.56*** (2.28)	-0.21 (0.54)	-0.31 (0.54)
Cons. Drought		21.50*** (3.70)		0.48** (0.22)		-0.06 (0.08)
Obs	27,138	27,138	27,138	27,138	27,138	27,138
Adj R-Sq	0.9032	0.9033	0.207	0.207	0.8862	0.8862
Severe Droughts (Cumulative PED > 320mm) excluding mild drought						
Drought (t)	198.34 (218.08)	218.78 (218.36)	-13.68 (9.85)	-13.20 (9.84)	0.95 (0.78)	0.89 (0.78)
Drought (t-1)	148.23 (129.33)	216.74* (130.34)	12.01 (11.23)	13.64 (11.30)	-0.16 (0.60)	-0.37 (0.63)
Drought (t-2)	37.36* (20.03)	88.29*** (21.44)	-0.70 (6.18)	0.51 (6.19)	0.25 (0.61)	0.09 (0.62)
Cons. Drought		24.11*** (3.88)		0.57** (0.23)		-0.07 (0.09)
Obs	24,378	24,378	24,378	24,378	24,378	24,378
Adj R-Sq	0.9122	0.9124	0.1927	0.1927	0.888	0.888

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

Table 2.25: Additional Regression results for debt and other financials of Dairy Farming adding farmland in the model (NZD in 000)

Indicators	Real Short-term-Debt	Real Long-term-Debt	Real Total Debt	Real Total Equity	Real Total Profit	Real Interest Paid
Model	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	29.77* (16.63)	47.96* (29.07)	62.76* (35.40)	158.34*** (45.67)	-22.75*** (3.77)	3.49* (1.84)
Drought (t-1)	45.96** (19.52)	41.73 (34.32)	78.13* (40.72)	164.95** (76.94)	-10.27*** (3.34)	0.46 (2.95)
Drought (t-2)	81.25*** (15.06)	108.35*** (41.29)	183.63*** (41.22)	122.29*** (47.16)	-38.09*** (4.22)	6.63** (3.14)
Cons. Drought	-0.99 (3.67)	13.01*** (4.91)	12.06** (5.64)	21.21*** (7.56)	-1.83*** (0.55)	1.35*** (0.38)
Farmland	0.68** (0.30	3.19*** (0.90)	3.82*** (0.80)	1.29* (0.74)	0.04 (0.05)	1.74*** (0.03)
Obs	25,665	25,665	25,665	25,665	25,665	25,665
Adj R-Sq	0.4361	0.7862	0.7964	0.8022	0.2543	0.7575
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	26.12 (17.60)	37.63 (32.79)	50.27 (39.41)	147.78*** (45.86)	-25.02*** (4.04)	3.40* (1.93)
Drought (t-1)	48.22** (20.92)	48.58 (36.69)	87.87** (43.95)	212.69*** (82.47)	-10.67*** (3.55)	0.70 (3.10)
Drought (t-2)	79.50*** (15.90)	107.34** (48.19)	180.35*** (48.01)	123.72** (54.25)	-35.29*** (4.43)	6.95** (3.53)
Cons. Drought	-3.38 (3.73)	13.82*** (5.38)	10.45* (6.08)	22.00*** (7.30)	-2.16*** (0.51)	1.51*** (0.41)
Farmland	0.63** (0.31)	3.16*** (0.96)	3.74*** (0.86)	1.28* (0.77)	0.04 (0.05)	0.17*** (0.03)
Obs	23,658	23,658	23,658	23,658	23,658	23,658
Adj R-Sq	0.3992	0.7807	0.7912	0.8012	0.2574	0.7509
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	47.31 (28.75)	125.75* (69.22)	141.27* (85.04)	158.80* (95.81)	-22.62*** (7.78)	5.07 (4.38)
Drought (t-1)	75.81** (29.61)	107.00*** (36.72)	161.53*** (47.31)	268.12** (105.19)	-26.55*** (5.25)	5.79* (3.36)
Drought (t-2)	99.25*** (19.19)	184.76*** (48.30)	279.22*** (54.79)	299.29*** (62.32)	-38.41*** (5.43)	9.15*** (3.49)
Cons. Drought	-1.47 (3.06)	24.64*** (6.28)	23.00*** (6.65)	41.01*** (7.74)	-2.06*** (0.75)	1.99*** (0.48)
Farmland	0.44 (0.27)	3.32*** (0.62)	3.66*** (0.64)	1.66** (0.85)	0.09 (0.07)	0.13*** (0.05)
Obs	16,665	16,665	16,665	16,665	16,665	16,665
Adj R-Sq	0.4357	0.8247	0.8299	0.7995	0.2742	0.7905

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

Table 2.26: Additional Regression results for debt and other financials of Sheep & Beef Farming adding farmland in the model (NZD in 000)

Indicators	Real Short-term-Debt	Real Long-term-Debt	Real Total Debt	Real Total Equity	Real Total Profit	Real Interest Paid
Model	(2)	(2)	(2)	(2)	(2)	(2)
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	14.25*** (4.12)	7.15 (5.03)	20.53*** (6.10)	35.84 (30.62)	1.02 (5.21)	0.33 (0.30)
Drought (t-1)	15.65*** (5.82)	3.48 (5.98)	18.08** (8.02)	33.05 (41.34)	1.25 (1.66)	-0.05 (0.31)
Drought (t-2)	15.80*** (5.83)	0.60 (5.90)	15.51* (8.38)	87.48** (37.27)	0.69 (2.24)	-0.10 (0.29)
Cons. Drought	1.83 (1.26)	8.38** (3.52)	10.27*** (3.63)	7.75 (6.45)	-0.49 (0.52)	0.20 (0.19)
Farmland	0.05** (0.02)	-0.03 (0.08)	0.02 (0.08)	0.06 (0.13)	0.02 (0.01)	0.00 (0.01)
Obs	27,237	27,237	27,237	27,237	27,237	27,237
Adj R-Sq	0.5662	0.9039	0.9015	0.9011	0.2023	0.8854
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	12.23*** (4.70)	6.00 (5.04)	17.89*** (6.51)	35.83 (32.32)	2.00 (5.45)	0.32 (0.29)
Drought (t-1)	16.46*** (5.58)	4.04 (5.93)	19.61** (7.92)	35.69 (43.50)	1.82 (1.78)	-0.14 (0.31)
Drought (t-2)	17.89*** (5.77)	0.45 (5.95)	17.33** (8.31)	96.94** (39.53)	1.50 (2.13)	-0.01 (0.29)
Cons. Drought	1.49 (1.29)	7.96*** (3.06)	9.60*** (3.32)	6.71 (6.27)	-0.65 (0.52)	0.22 (0.15)
Farmland	0.04 (0.02)	-0.01 (0.07)	0.03 (0.07)	0.08 (0.15)	0.02 (0.01)	0.00 (0.01)
Obs	25,143	25,143	25,143	25,143	25,143	25,143
Adj R-Sq	0.4886	0.9113	0.9069	0.9014	0.2282	0.8976
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	29.29*** (10.02)	9.20 (14.80)	33.50* (17.31)	-51.56* (30.96)	-14.29*** (3.67)	0.97 (0.87)
Drought (t-1)	9.84 (6.00)	12.81 (8.68)	21.36** (10.25)	148.70* (76.16)	7.15 (5.20)	0.01 (0.58)
Drought (t-2)	15.94*** (5.90)	4.46 (7.32)	18.54* (9.65)	124.97** (49.63)	-1.46 (3.23)	0.03 (0.48)
Cons. Drought	0.40 (1.42)	9.10** (4.06)	9.44** (4.42)	21.96*** (5.91)	0.27 (0.56)	0.19 (0.23)
Farmland	0.02 (0.01)	-0.02 (0.01)	0.00 (0.01)	0.03 (0.06)	0.01 (0.01)	0.00 (0.01)
Obs	16,959	16,959	16,959	16,959	16,959	16,959
Adj R-Sq	0.7324	0.6037	0.7103	0.6793	0.1273	0.7617

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

Table 2.27: Additional Regression results for a short-term and long-term debt of Dairy Farming by sizes adding farmland in the model (NZD in 000)

Indicators	**Real Short-term-Debt**			**Real Long-term-Debt**		
	Small Farms	**Medium Farms**	**Large Farms**	**Small Farms**	**Medium Farms**	**Large Farms**
Model	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	30.59*** (10.23)	40.85*** (14.17)	-37.17 (100.75)	16.34 (14.99)	8.44 (35.79)	111.79 (121.98)
Drought (t-1)	2.93 (12.60)	46.39*** (13.53)	85.56 (135.50)	31.25** (15.42)	54.67 (39.53)	-23.22 (128.50)
Drought (t-2)	26.54** (13.35)	74.86*** (16.89)	98.23 (79.74)	26.72 (16.82)	100.95** (51.37)	136.59 (155.94)
Cons. Drought	1.14 (2.75)	1.86 (4.04)	-26.40* (15.28)	7.89* (4.44)	9.08 (6.19)	25.39 (27.43)
Farm land	0.87 (0.72)	1.54*** (0.47)	0.62 (0.68)	1.08 (1.30)	4.54*** (1.00)	3.39** (1.60)
Obs	8,595	13,275	3,795	8,595	13,275	3,795
Adj R-Sq	0.3511	0.5853	0.377	0.7921	0.7338	0.8295
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	30.38*** (11.02)	37.95*** (14.08)	-41.55 (106.78)	12.66 (15.24)	1.21 (39.70)	65.45 (129.43)
Drought (t-1)	4.80 (14.15)	43.16*** (14.05)	94.93 (145.70)	25.73 (16.45)	52.23 (40.76)	13.73 (143.11)
Drought (t-2)	30.37** (14.32)	70.75*** (17.97)	85.43 (83.91)	21.81 (17.48)	106.36* (59.86)	65.23 (175.20)
Cons. Drought	-0.32 (2.82)	-0.91 (4.25)	-28.38* (15.93)	6.59 (4.82)	10.09 (6.17)	23.71 (28.41)
Farm Size	0.24 (0.58)	1.54*** (0.48)	0.56 (0.70)	1.59 (1.35)	4.66*** (1.04)	3.33** (1.65)
Obs	7,815	12,255	3,588	7,815	12,255	3,588
Adj R-Sq	0.3308	0.526	0.361	0.7944	0.7248	0.8265
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	25.89 (16.84)	36.00 (32.72)	61.88 (180.81)	42.95 (30.94)	49.07 (58.36)	536.02 (461.00)
Drought (t-1)	8.74 (18.19)	71.75*** (20.08)	145.28 (228.90)	61.17** (25.73)	126.61*** (37.83)	163.22 (194.92)
Drought (t-2)	51.94*** (15.58)	109.57*** (23.43)	24.26 (162.32)	54.35** (25.84)	168.44*** (60.09)	267.24 (176.02)
Cons. Drought	0.08 (2.96)	3.73 (4.20)	-20.68 (15.16)	10.36* (5.71)	18.63*** (6.76)	51.14 (40.08)
Farm land	0.73 (0.79)	1.29*** (0.46)	-0.08 (0.83)	0.55 (1.66)	4.90*** (0.96)	3.78** (1.91)
Obs	5,475	8,700	2,490	5,475	8,700	2,490
Adj R-Sq	0.3773	0.5874	0.3771	0.771	0.8037	0.8503

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

Table 2.28: Additional Regression results for a short-term and long-term debt of Sheep & Beef Farming by sizes adding farmland in the model (NZD in 000)

Indicators	Real Short-term-Debt			Real Long-term-Debt		
	Small Farms	**Medium Farms**	**Large Farms**	**Small Farms**	**Medium Farms**	**Large Farms**
Model	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	7.10* (4.06)	3.05 (5.16)	48.17*** (18.21)	-0.49 (3.43)	7.40 (8.09)	21.57 (23.93)
Drought (t-1)	3.38 (4.85)	3.06 (5.12)	67.49** (29.30)	1.46 (4.85)	1.59 (6.92)	3.99 (29.83)
Drought (t-2)	5.42 (5.92)	9.03* (5.11)	48.47* (25.41)	-1.28 (6.61)	-0.83 (6.54)	0.58 (23.63)
Cons. Drought	-0.27 (1.08)	0.74 (2.90)	7.58* (4.07)	2.53** (1.08)	-1.39 (3.80)	29.47** (14.57)
Farmland	0.07* (0.04)	0.13* (0.08)	0.05** (0.02)	0.08 (0.06)	-0.03 (0.10)	0.04 (0.09)
Obs	15,624	6,420	5,193	15,624	6,420	5,193
Adj R-Sq	0.385	0.4075	0.5924	0.7939	0.7617	0.9091
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	7.14* (4.27)	2.04 (4.96)	41.18* (22.66)	-0.57 (3.40)	8.32 (8.34)	15.93 (25.25)
Drought (t-1)	5.42 (4.96)	0.95 (5.11)	69.96** (27.85)	1.02 (5.23)	2.36 (6.96)	8.67 (29.57)
Drought (t-2)	5.16 (6.44)	8.24 (5.09)	63.656*** (23.64)	-1.50 (6.63)	-0.30 (7.14)	4.50 (24.19)
Cons. Drought	-0.47 (1.08)	0.85 (3.24)	7.26* (4.31)	2.70** (1.21)	-0.54 (3.68)	28.40** (13.21)
Farmland	0.08* (0.05)	0.14** (0.07)	0.04** (0.02)	0.08 (0.07)	-0.05 (0.10)	-0.02 (0.08)
Obs	14,466	6,015	4,662	14,466	6,015	4,662
Adj R-Sq	0.3741	0.4175	0.5013	0.754	0.7483	0.9179
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	7.85 (5.94)	7.01 (23.08)	101.82** (40.54)	1.44 (10.62)	16.67 (22.61)	-3.91 (64.22)
Drought (t-1)	2.32 (6.04)	16.73 (13.08)	15.09 (24.44)	-3.91 (5.24)	-13.56 (15.19)	70.18* (37.37)
Drought (t-2)	5.16 (5.82)	15.85 (10.29)	46.58* (24.10)	-2.44 (6.84)	-0.10 (12.51)	9.29 (28.89)
Cons. Drought	-0.13 (1.38)	3.86 (5.13)	-1.29 (3.18)	1.36 (1.12)	-5.50 (5.68)	40.02** (17.48)
Farmland	0.08 (0.05)	0.13 (0.09)	0.02 (0.02)	0.07 (0.08)	0.04 (0.10)	-0.04 (0.06)
Obs	9,639	4,134	3,186	9,639	4,134	3,186
Adj R-Sq	0.4241	0.3248	0.8016	0.8094	0.7478	0..5137

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

Table 2.29: Additional Regression results for total debt and equity of Dairy Farming by sizes adding farmland in the model (NZD in 000)

Indicators	Real Total Debt			Real Total Equity		
	Small Farms	Medium Farms	Large Farms	Small Farms	Medium Farms	Large Farms
Model	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	40.99** (17.04)	38.85 (39.20)	36.43 (140.52)	180.92*** (38.12)	132.44* (74.51)	61.58 (144.04)
Drought (t-1)	26.96* (16.24)	90.47** (41.60)	74.21 (174.90)	201.63*** (33.77)	238.88* (141.33)	-253.40 (163.31)
Drought (t-2)	56.82*** (19.64)	164.92*** (53.13)	242.75 (168.86)	156.50*** (34.41)	151.92** (76.40)	-218.41 (146.90)
Cons. Drought	9.60** (4.81)	11.05* (6.46)	-1.24 (31.03)	25.13*** (7.86)	19.22* (10.56)	-20.42 (27.34)
Farmland	2.18* (1.32)	5.94*** (1.15)	4.07*** (1.28)	1.51 (2.40)	2.83** (1.39)	2.29 (1.61)
Obs	8,595	13,275	3,795	8,595	13,275	3,795
Adj R-Sq	0.8146	0.7616	0.8205	0.6549	0.5239	0.9506
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	36.50** (17.26)	29.04 (42.88)	-6.26 (153.21)	162.44*** (38.24)	132.65* (78.00)	66.04 (139.23)
Drought (t-1)	23.88 (17.29)	84.42** (42.71)	125.75 (196.77)	217.32*** (36.12)	292.11* (153.51)	-146.08 (163.88)
Drought (t-2)	59.46*** (21.51)	165.99*** (61.04)	154.69 (192.83)	167.46*** (36.86)	173.33** (86.41)	-308.33* (171.92)
Cons. Drought	7.08 (4.97)	9.43 (6.63)	-5.00 (32.10)	20.18*** (7.29)	23.58** (10.75)	-11.41 (27.43)
Farmland	2.00 (1.37)	6.06*** (1.18)	3.94*** (1.31)	1.12 (2.58)	2.78* (1.50)	2.23 (1.63)
Obs	7,815	12,255	3,588	7,815	12,255	3,588
Adj R-Sq	0.8092	0.7502	0.8189	0.65	0.5057	0.9541
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	63.92** (29.22)	80.05 (63.99)	464.38 (585.36)	248.91*** (84.56)	170.00* (93.55)	-156.21 (605.08)
Drought (t-1)	58.15** (26.18)	175.78*** (43.01)	324.98 (267.14)	196.77*** (43.33)	337.54* (204.52)	38.65 (203.40)
Drought (t-2)	94.51*** (26.80)	257.86*** (65.03)	331.89 (247.60)	293.27*** (48.62)	320.17*** (80.39)	13.22 (282.31)
Cons. Drought	10.74* (5.90)	20.78*** (8.04)	34.95 (42.53)	31.96*** (7.73)	38.06*** (12.00)	35.79 (31.22)
Farm land	1.82 (1.62)	6.00*** (1.12)	3.85** (1.57)	1.94 (2.68)	2.18 (1.93)	3.25* (1.88)
Obs	5,475	8,700	2,490	5,475	8,700	2,490
Adj R-Sq	0.8132	0.8132	0.8376	0.6314	0.3802	0.9656

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

Table 2.30: Additional Regression results for total debt and equity of Sheep & Beef Farming by sizes adding farmland in the model (NZD in 000)

Indicators	Real Total Debt			Real Total Equity		
	Small Farms	Medium Farms	Large Farms	Small Farms	Medium Farms	Large Farms
Model	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	3.60 (4.81)	8.03 (9.54)	76.76*** (28.00)	10.16 (14.62)	53.25 (40.36)	126.00 (158.18)
Drought (t-1)	2.58 (6.36)	2.92 (8.38)	74.69* (40.74)	-20.64 (33.16)	78.60 (74.77)	57.48 (69.55)
Drought (t-2)	2.40 (8.42)	4.05 (8.62)	53.01 (36.28)	50.43*** (17.90)	170.01** (81.82)	17.57 (48.26)
Cons. Drought	2.18 (1.38)	-0.62 (5.43)	37.61*** (14.37)	2.12 (3.54)	39.15*** (13.01)	5.97 (19.71)
Farmland	0.18 (0.07)	0.12 (0.12)	0.00 (0.01)	-0.47** (0.20)	1.99 (2.38)	0.07 (0.14)
Obs	15,624	6,420	5,193	15,624	6,420	5,193
Adj R-Sq	0.7048	0.7572	0.9112	0.311	0.8404	0.9653
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	3.72 (4.80)	8.15 (9.78)	66.32** (32.24)	10.66 (15.33)	59.54 (44.77)	118.42 (165.75)
Drought (t-1)	3.91 (6.90)	2.60 (8.71)	82.59** (39.72)	-23.80 (36.59)	88.58 (81.74)	69.51 (73.14)
Drought (t-2)	1.32 (8.67)	3.54 (9.01)	73.43** (35.17)	53.15*** (19.41)	184.43** (87.88)	38.85 (50.01)
Cons. Drought	2.07 (1.48)	0.43 (5.62)	36.75*** (13.74)	0.61 (3.60)	40.55*** (14.62)	4.98 (19.09)
Farmland	0.19** (0.08)	0.10 (0.12)	0.02 (0.08)	-0.46 (0.20)	2.04 (2.50)	0.10 (0.17)
Obs	14,466	6,015	4,662	14,466	6,015	4,662
Adj R-Sq	0.6668	0.7373	0.9186	0.2843	0.8398	0.9667
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	4.64 (12.50)	19.14 (22.24)	92.27 (75.75)	-20.96 (15.10)	-98.65 (78.62)	-108.88 (126.01)
Drought (t-1)	-2.49 (7.92)	-0.24 (22.22)	88.58** (40.92)	43.37*** (15.49)	274.80 (173.48)	145.84* (85.75)
Drought (t-2)	1.25 (9.11)	9.82 (17.11)	51.43 (39.19)	59.94*** (16.03)	238.75** (109.21)	50.80 (66.22)
Cons. Drought	1.31 (1.51)	-1.82 (9.01)	38.68** (18.26)	9.10** (3.80)	74.92*** (29.00)	26.40 (17.18)
Farmland	0.15** (0.07)	0.19 (0.15)	-0.02 (0.05)	-0.33 (0.23)	2.24 (2.91)	0.03 (0.07)
Obs	9,639	4,134	3,186	9,639	4,134	3,186
Adj R-Sq	0.7385	0.7327	0.6693	0.7123	0.8075	0.9246

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

Table 2.31: Additional Regression results for profit and interest of Dairy Farming by sizes adding farmland in the model (NZD in 000)

Indicators	Real Total Profit			Real Interest Paid		
	Small Farms	**Medium Farms**	**Large Farms**	**Small Farms**	**Medium Farms**	**Large Farms**
Model	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	-7.96** (3.30)	-20.92*** (4.85)	-60.93*** (17.58)	2.85*** (0.97)	1.48 (2.90)	5.28 (6.99)
Drought (t-1)	-6.16** (2.98)	-13.01*** (3.76)	-5.70 (18.24)	1.76* (0.95)	-0.66 (3.69)	-4.41 (10.97)
Drought (t-2)	-16.51*** (3.91)	-40.50*** (5.23)	-61.28*** (18.38)	-0.58 (0.92)	9.36** (4.50)	-1.59 (11.79)
Cons. Drought	-1.14** (0.49)	-2.61*** (0.73)	-2.11 (2.78)	0.65** (0.31)	1.30*** (0.48)	2.26 (1.60)
Farm land	0.06 (0.14)	0.07 (0.08)	0.09 (0.11)	0.14 (0.11)	0.12 (0.14)	0.14** (0.07)
Obs	8,595	13,275	3,795	8,595	13,275	3,795
Adj R-Sq	0.3215	0.3502	0.1598	0.7417	0.6662	0.8134
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	-11.91*** (3.26)	-23.34*** (5.38)	-57.98*** (18.20)	2.83*** (1.00)	1.38 (3.13)	5.13 (6.86)
Drought (t-1)	-10.43*** (3.08)	-13.45*** (3.99)	5.96 (19.02)	1.73 (1.06)	-1.48 (4.03)	-1.62 (10.73)
Drought (t-2)	-10.94*** (3.84)	-36.01*** (5.25)	-62.48*** (19.90)	-0.56 (0.99)	10.73** (5.04)	-4.55 (13.06)
Cons. Drought	-1.38*** (0.44)	-3.15*** (0.64)	-0.79 (2.90)	0.76** (0.33)	1.41*** (0.51)	2.29 (1.66)
Farm land	0.03 (0.15)	0.04 (0.08)	0.10 (0.12)	0.13 (0.11)	0.12 (0.15)	0.14** (0.07)
Obs	7,815	12,255	3,588	7,815	12,255	3,588
Adj R-Sq	0.3347	0.3855	0.1536	0.7362	0.6566	0.8106
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	11.27 (11.06)	-15.54* (8.50)	-114.09** (44.85)	3.94** (1.71)	2.27 (3.72)	9.25 (29.81)
Drought (t-1)	-17.01*** (5.69)	-26.31*** (7.05)	-43.90* (24.48)	4.03*** (1.56)	6.53** (2.55)	2.64 (20.08)
Drought (t-2)	-16.40*** (5.82)	-38.06*** (6.75)	-57.23** (27.05)	-0.27 (1.42)	8.57** (3.78)	8.13 (13.98)
Cons. Drought	-1.15* (0.65)	-2.32** (0.91)	-5.45 (3.69)	0.77* (0.44)	1.79*** (0.58)	3.17 (2.31)
Farm land	0.07 (0.21)	0.05 (0.10)	0.16 (0.17)	0.15 (0.15)	0.27*** (0.06)	0.06 (0.11)
Obs	5,475	8,700	2,490	5,475	8,700	2,490
Adj R-Sq	0.2919	0.3832	0.1563	0.6969	0.805	0.8034

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

Table 2.32: Additional Regression results for profit and interest of Sheep & Beef Farming by sizes adding farmland in the model (NZD in 000)

Indicators	Real Total Profit			Real Interest Paid		
	Small Farms	Medium Farms	Large Farms	Small Farms	Medium Farms	Large Farms
Model	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**	**(2)**
All Droughts (NZPGI≤30 and consecutive days≥10)						
Drought (t)	-4.64* (2.44)	9.06 (11.50)	12.46 (16.58)	0.09 (0.23)	-0.17 (0.70)	1.21 (1.18)
Drought (t-1)	-0.07 (1.70)	6.34 (5.36)	0.96 (5.29)	-0.01 (0.24)	-0.57 (0.65)	-0.07 (1.39)
Drought (t-2)	1.68 (1.92)	8.83 (9.13)	-11.38 (7.19)	-0.17 (0.22)	-1.24** (0.58)	1.13 (1.30)
Cons. Drought	-0.36 (0.37)	0.08 (0.93)	-0.93 (1.67)	0.10* (0.06)	-0.45 (0.53)	0.88 (0.69)
Farmland	-0.02 (0.02)	0.56 (0.57)	0.01 (0.01)	0.02** (0.01)	0.01 (0.01)	0.00 (0.01)
Obs	15,624	6,420	5,193	15,624	6,420	5,193
Adj R-Sq	0.1254	0.1739	0.183	0.8212	0.6542	0.8931
Mild Droughts (NZPGI≤30 and consecutive days≥10) excluding severe drought						
Drought (t)	-4.49* (2.52)	10.27 (12.33)	16.41 (17.46)	0.07 (0.22)	-0.10 (0.77)	1.10 (1.21)
Drought (t-1)	-0.13 (1.77)	6.43 (5.80)	4.62 (6.46)	-0.13 (0.24)	-0.68 (0.71)	0.07 (1.42)
Drought (t-2)	1.63 (1.98)	8.79 (9.81)	-5.75 (4.41)	-0.15 (0.22)	-1.12* (0.59)	1.12 (1.32)
Cons. Drought	-0.30 (0.40)	0.06 (1.00)	-1.79 (1.66)	0.10* (0.05)	-0.42 (0.59)	1.00** (0.39)
Farmland	-0.02 (0.02)	0.58 (0.60)	0.02 (0.02)	0.02** (0.01)	0.00 (0.02)	0.00 (0.01)
Obs	14,466	6,015	4,662	14,466	6,015	4,662
Adj R-Sq	0.1136	0.1674	0.2597	0.7897	0.631	0.9088
Severe Droughts (NZPGI≤30 and consecutive days≥10) excluding mild drought						
Drought (t)	-5.06** (2.39)	-11.78** (5.86)	-44.49*** (15.53)	0.32 (0.59)	1.08 (1.55)	3.14 (3.05)
Drought (t-1)	3.44 (5.13)	17.47 (15.95)	8.87 (9.15)	-0.05 (0.34)	-3.07 (2.23)	1.78 (1.90)
Drought (t-2)	2.54 (2.81)	-3.43 (5.83)	-14.73 (15.39)	0.10 (0.27)	-1.73 (1.53)	1.22 (1.98)
Cons. Drought	-0.08 (0.39)	1.66 (1.49)	1.13 (2.10)	0.11* (0.07)	-0.98 (0.93)	1.14* (0.65)
Farmland	-0.04 (0.03)	0.44 (0.48)	0.00 (0.01)	0.02** (0.01)	0.03* (0.01)	0.00 (0.00)
Obs	9,639	4,134	3,186	9,639	4,134	3,186
Adj R-Sq	0.1373	0.1145	0.0716	0.8222	0.5982	0.7594

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

Table 2.33: Regression results for Debt of Dairy Farming using NZDI as drought indicator (NZD in 000)

Indicators	Short-term Debt		Long-term Debt		Total Debt	
Model	**1**	**2**	**1**	**2**	**1**	**2**
All Droughts						
Drought (t)	18.84	10.80	14.70	17.40	34.22	25.90
	(19.41)	(24.27)	(27.45)	(29.06)	(31.92)	(34.87)
Drought (t-1)	-35.85*	-44.25*	-45.98*	-43.65	-83.43***	-92.50***
	(19.60)	(25.34)	(23.66)	(27.22)	(28.71)	(33.43)
Drought (t-2)	-14.40	-15.04	35.21	33.74	19.57	17.10
	(25.99)	(25.95)	(25.12)	(25.24)	(30.55)	(30.55)
Cons. Drought		13.79		-7.97		10.49
		(15.53)		(15.58)		(18.64)
Farmland		-0.04		0.94		0.97
		(0.5)		(1.26)		(1.21)
Obs	14,988	14,973	14,988	14,973	14,988	14,973
Adj R-Sq	0.5957	0.5957	0.9145	0.9147	0.9243	0.9244
Mild Droughts (excluding severe drought)						
Drought (t)	17.13	3.11	8.40	-4.30	28.79	-1.63
	(24.09)	(34.06)	(34.28)	(39.39)	(39.94)	(47.28)
Drought (t-1)	-41.63*	-49.92*	-40.73*	-49.50*	-82.95***	-102.34***
	(21.55)	(27.02)	(24.5)	(29.17)	(29.95)	(35.83)
Drought (t-2)	-3.36	-3.70	31.61	29.21	27.56	24.48
	(27.21)	(26.89)	(27.49)	(27.67)	(32.73)	(32.73)
Cons. Drought		17.67		13.94		36.06
		(19.93)		(18.88)		(22.91)
Farmland		-0.10		0.90		0.88
		(0.55)		(1.43)		(1.37)
Obs	12,942	12,936	12,942	12,936	12,942	12,936
Adj R-Sq	0.5675	0.5676	0.9068	0.907	0.9185	0.9187
Severe Droughts (excluding mild drought)						
Drought (t)	-1.11	-6.21	-17.58	-6.96	-13.32	-7.93
	(21.61)	(23.13)	(23.86)	(24.77)	(29.68)	(31.01)
Drought (t-1)	-44.46*	-49.90**	-57.19*	-49.00	-107.61***	-105.24***
	(22.76)	(24.02)	(30.56)	(30.85)	(36.26)	(36.77)
Drought (t-2)	16.74	18.58	21.14	15.55	38.16	34.22
	(21.88)	(21.91)	(26.63)	(26.93)	(34.18)	(34.26)
Cons. Drought		40.89*		-82.62***		-41.51
		(21.88)		(29.66)		(31.18)
Farmland		-0.08		0.78		0.78
		(0.49)		(1.39)		(1.32)
Obs	12,825	12,810	12,825	12,810	12,825	12,810
Adj R-Sq	0.5712	0.5712	0.9122	0.9123	0.9223	0.9224

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

Table 2.34: Regression results for Debt of Sheep & Beef Farming using NZDI as drought indicator (NZD in 000)

Indicators	Short-term Debt		Long-term Debt		Total Debt	
Model	1	2	1	2	1	2
All Droughts						
Drought (t)	14.45*	10.65	-3.26	0.42	10.39	10.46
	(7.64)	(6.99)	(5.21)	(5.79)	(7.89)	(8.44)
Drought (t-1)	-1.07	-5.36	1.00	5.26	-1.82	-1.64
	(6.43)	(6.45)	(4.74)	(6.11)	(7.17)	(8.81)
Drought (t-2)	17.79**	18.03**	-5.56	-5.81	11.04	11.02
	(7.71)	(7.78)	(6.44)	(6.41)	(8.23)	(8.19)
Cons. Drought		6.58		-6.38		-0.12
		(7.73)		(5.17)		(9.11)
Farmland		0.02		0.02		0.03
		(0.01)		(0.03)		(0.04)
Obs	15,654	15,639	15,654	15,639	15,654	15,639
Adj R-Sq	0.5829	0.5826	0.708	0.708	0.7436	0.7436
Mild Droughts (excluding severe drought)						
Drought (t)	13.84	8.26	-1.94	3.22	10.45	10.05
	(10.33)	(10.14)	(6.27)	(7.61)	(10.97)	(12.41)
Drought (t-1)	-3.56	-7.81	2.26	6.31	-2.91	-3.09
	(5.97)	(6.57)	(4.72)	(6.18)	(7.03)	(8.91)
Drought (t-2)	15.15*	15.27*	-2.92	-3.00	10.72	10.75
	(7.91)	(7.93)	(6.84)	(6.81)	(9.06)	(9.04)
Cons. Drought		7.61		-7.05		0.54
		(7.94)		(5.59)		(9.87)
Farmland		0.01		0.02		0.03
		(0.01)		(0.03)		(0.04)
Obs	14,490	14,475	14,490	14,475	14,490	14,475
Adj R-Sq	0.5805	0.5802	0.6968	0.6968	0.735	0.735
Severe Droughts (excluding mild drought)						
Drought (t)	-7.73	-7.95	0.87	1.10	-6.31	-6.24
	(10.51)	(10.91)	(6.7)	(6.95)	(10.55)	(10.96)
Drought (t-1)	-15.16	-15.31	-2.20	-1.99	-16.22	-16.10
	(12.77)	(13.09)	(8.37)	(8.56)	(13.33)	(13.64)
Drought (t-2)	3.022989	2.30	2.34	2.37	4.22	3.51
	(8.93)	(8.86)	(7.41)	(7.39)	(10.11)	(10.05)
Cons. Drought		0.33		-3.13		-3.55
		(8.54)		(4.77)		(9.52)
Farmland		0.01		0.02		0.03
		(0.01)		(0.03)		(0.04)
Obs	13,374	13,365	13,374	13,365	13,374	13,365
Adj R-Sq	0.6472	0.647	0.6877	0.6877	0.7372	0.7372

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

Table 2.35: Regression results for other financials of Dairy Farming using NZDI as drought indicator (NZD in 000)

Indicators	Total Equity		Total Profit		Total Interest	
Model	**1**	**2**	**1**	**2**	**1**	**2**
			All Droughts			
Drought (t)	68.69	39.84	26.99***	-1.73	-0.86	0.55
	(49.28)	(53.31)	(6.94)	(6.09)	(1.73)	(2.02)
Drought (t-1)	-7.64	-42.43	3.47	-25.21***	1.31	2.72
	(41.45)	(46.02)	(5.09)	(5.37)	(1.86)	(2.11)
Drought (t-2)	27.78	26.55	-38.84***	-41.41***	-2.98	-2.83*
	(43.47)	(43.86)	(6.23)	(6.06)	(1.72)	(1.67)
Cons. Drought		64.99**		46.80***		-2.25*
		(32.76)		(9.61)		(1.35)
Farmland		0.42		0.10		-0.01
		(0.57)		(0.11)		(0.07)
Obs	14,988	14,973	14,988	14,973	14,988	14,973
Adj R-Sq	0.8886	0.8903	0.2505	0.2553	0.916	0.916
			Mild Droughts (excluding severe drought)			
Drought (t)	65.91	18.24	33.80***	6.79	1.04	2.90
	(63.59)	(72.51)	(8.92)	(8.31)	(2.26)	(2.97)
Drought (t-1)	-22.66	-50.90	-4.42	-20.73***	2.33	3.47
	(45.04)	(50.12)	(5.14)	(5.57)	(2.13)	(2.25)
Drought (t-2)	16.89	15.52	-43.01***	-44.38***	-2.17	-2.05
	(43.39)	(43.69)	(6.85)	(6.71)	(1.87)	(1.81)
Cons. Drought		68.75*		33.47***		-2.28
		(37.22)		(10.91)		(1.76)
Farmland		0.56		0.12		-0.02
		(0.63)		(0.13)		(0.07)
Obs	12,942	12,936	12,942	12,936	12,942	12,936
Adj R-Sq	0.8773	0.8784	0.2258	0.2286	0.911	0.9111
			Severe Droughts (excluding mild drought)			
Drought (t)	51.78	39.74	54.31***	43.72***	-0.42	0.68
	(34.55)	(37.17)	(6.59)	(5.16)	(1.68)	(1.67)
Drought (t-1)	18.58	-3.66	56.54***	45.22***	0.10	1.30
	(45.49)	(46.96)	(7.15)	(6.73)	(2.86)	(2.78)
Drought (t-2)	12.59	28.15	-9.99	-6.98	1.57	1.23
	(42.15)	(39.71)	(7.66)	(7.12)	(2.21)	(2.17)
Cons. Drought		126.47**		76.72***		-8.14***
		(59.85)		(23.05)		(2.11)
Farmland		0.47		0.12		-0.01
		(0.59)		(0.12)		(0.07)
Obs	12,825	12,810	12,825	12,810	12,825	12,810
Adj R-Sq	0.9054	0.9065	0.276	0.2792	0.9177	0.9177

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

Table 2.36: Regression results for other financials of Sheep & Beef Farming using NZDI as drought indicator (NZD in 000)

Indicators	Total Equity		Total Profit		Total Interest	
Model	**1**	**2**	**1**	**2**	**1**	**2**
All Droughts						
Drought (t)	23.29	14.59	-1.62	1.60	-0.33	-0.17
	(14.04)	(17.41)	(2.87)	(4.33)	(0.28)	(0.38)
Drought (t-1)	8.67	0.06	-5.00	-1.28	0.33	0.52
	(17.77)	(24.92)	(5.34)	(3.36)	(0.33)	(0.46)
Drought (t-2)	8.37	9.52	6.45	6.15	0.10	0.08
	(19.92)	(19.57)	(8.98)	(8.87)	(0.31)	(0.31)
Cons. Drought		13.61		-5.63		-0.29
		(16.72)		(3.95)		(0.29)
Farmland		0.16*		0.01		0.00
		(0.09)		(0.01)		(0.01)
Obs	15,654	15,639	15,654	15,639	15,654	15,639
Adj R-Sq	0.9659	0.966	0.3674	0.3675	0.8922	0.8924
Mild Droughts (excluding severe drought)						
Drought (t)	50.81**	50.79**	-5.13	-1.30	-0.51	-0.40
	(18.93)	(21.04)	(7.31)	(9.02)	(0.32)	(0.48)
Drought (t-1)	-4.31	-2.91	-3.92	-0.92	0.49	0.58
	(21.67)	(26.97)	(3.73)	(2.41)	(0.34)	(0.47)
Drought (t-2)	22.24	22.80	2.15	2.01	0.14	0.13
	(18.57)	(18.48)	(4.55)	(4.55)	(0.31)	(0.31)
Cons. Drought		-1.73		-5.28		-0.17
		(15.71)		(4.14)		(0.34)
Farmland		0.16*		0.01		0.00
		(0.09)		(0.01)		(0.01)
Obs	14,490	14,475	14,490	14,475	14,490	14,475
Adj R-Sq	0.9638	0.9639	0.2848	0.2849	0.8897	0.8898
Severe Droughts (excluding mild drought)						
Drought (t)	-37.88**	-39.61**	1.89	2.11	0.26	0.26
	(18.74)	(19.44)	(12.33)	(12.68)	(0.38)	(0.41)
Drought (t-1)	-57.74**	-59.07**	4.34	4.55	0.18	0.18
	(24.75)	(25.14)	(12.63)	(12.93)	(0.75)	(0.76)
Drought (t-2)	12.32	13.11	8.09	8.06	0.28	0.21
	(29.01)	(29.11)	(16.14)	(16.09)	(0.57)	(0.57)
Cons. Drought		23.51		-2.89		-0.17
		(21.05)		(5.32)		(0.31)
Farmland		0.16*		0.01		0.00
		(0.09)		(0.01)		(0.01)
Obs	13,374	13,365	13,374	13,365	13,374	13,365
Adj R-Sq	0.9617	0.9618	0.5643	0.5644	0.8903	0.8905

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

Table 2.37: Regression results for Real Short-term-Debt of Dairy Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	**1**	**2**	**1**	**2**	**1**	**2**
			All Droughts			
Drought (t)	16.43	17.39	18.90	20.16	-45.26	-96.18
	(16.38)	(20.95)	(19.17)	(22.89)	(115.18)	(158.95)
Drought (t-1)	-42.66**	-41.25**	-19.69	-19.52	-115.57	-165.78
	(17.16)	(18.48)	(18.16)	(23.71)	(110.29)	(158.81)
Drought (t-2)	-18.41	-18.46	3.44	1.27	-122.69	-128.22
	(16.89)	(16.77)	(24.56)	(24.39)	(171.62)	(175.91)
Cons. Drought		-3.68		-2.68		81.21
		(16.27)		(17.5)		(93.27)
Farmland		1.21		1.64**		-1.04
		(0.99)		(0.64)		(1.59)
Obs	4,659	4,650	7,890	7,887	2,436	2,436
Adj R-Sq	0.4108	0.4107	0.7074	0.7085	0.5566	0.5582
			Mild Droughts (excluding severe drought)			
Drought (t)	26.13	33.39	14.60	14.12	-98.43	-211.02
	(21.04)	(33.92)	(22.48)	(30.05)	(141.41)	(225.27)
Drought (t-1)	-55.46***	-50.75**	-23.59	-24.81	-94.44	-163.58
	(19.23)	(19.86)	(20.42)	(25.39)	(107.72)	(157.81)
Drought (t-2)	-28.68	-28.23	7.98	5.70	-46.90	-51.60
	(18.05)	(17.78)	(27.68)	(27.47)	(170.01)	(173.57)
Cons. Drought		-10.99		-0.28		135.75
		(24.32)		(21.85)		(122.54)
Farmland		1.14		1.67**		-1.17
		(1.08)		(0.69)		(1.69)
Obs	3,852	3,849	6,855	6,852	2,232	2,232
Adj R-Sq	0.4199	0.4198	0.6842	0.6854	0.5254	0.5277
			Severe Droughts (excluding mild drought)			
Drought (t)	-14.36	-15.28	3.99	-0.47	131.90	137.36
	(18.67)	(19.05)	(20.09)	(20.79)	(193.76)	(204.41)
Drought (t-1)	-72.43***	-74.84***	-57.24**	-63.32**	239.61	266.49
	(20.06)	(21.41)	(27.26)	(28.22)	(192.1)	(203.12)
Drought (t-2)	-5.04	-5.97	10.00	10.14	223.55	220.65
	(20.09)	(20.37)	(20.68)	(20.75)	(188.29)	(188.82)
Cons. Drought		6.56		40.57		-34.53
		(33.99)		(28.12)		(136.51)
Farmland		1.25		1.49**		-1.26
		(1.15)		(0.65)		(1.77)
Obs	3,945	3,939	6,756	6,753	2,118	2,118
Adj R-Sq	0.4321	0.4319	0.6863	0.6874	0.5391	0.5414

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

Table 2.38: Regression results for Real Long-term-Debt of Dairy Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	**1**	**2**	**1**	**2**	**1**	**2**
All Droughts						
Drought (t)	3.35	4.34	-11.77	-17.11	150.72	207.96
	(17.64)	(19.58)	(27.19)	(29.31)	(182.37)	(201.55)
Drought (t-1)	3.77	4.17	-74.66**	-81.77**	-122.62	-79.14
	(12.88)	(15.62)	(29.33)	(32.44)	(148.77)	(189.56)
Drought (t-2)	1.44	2.11	36.95	33.04	205.32	222.67
	(12.21)	(12.54)	(34.9)	(34.66)	(154.32)	(157.57)
Cons. Drought		0.45		7.84		-86.44
		(13.31)		(20.81)		(94.65)
Farmland		-0.88		2.79***		2.70
		(1.79)		(0.9)		(1.71)
Obs	4,659	4,650	7,890	7,887	2,436	2,436
Adj R-Sq	0.894	0.894	0.8861	0.8863	0.9351	0.9364
Mild Droughts (excluding severe drought)						
Drought (t)	2.43	3.04	-9.83	-38.69	123.43	193.17
	(24.15)	(28.67)	(32.73)	(37.99)	(221.98)	(274.72)
Drought (t-1)	4.36	4.01	-66.85**	-85.81**	-121.41	-99.83
	(13.96)	(16.65)	(28.99)	(33.77)	(147.04)	(197.73)
Drought (t-2)	0.26	0.70	36.68	32.91	187.75	197.89
	(15.71)	(15.76)	(34.68)	(34.56)	(176.91)	(179.91)
Cons. Drought		1.30		35.54		-77.52
		(15.69)		(24.2)		(123.54)
Farmland		-1.25		2.54***		2.82
		(2.01)		(0.91)		(1.82)
Obs	3,852	3,849	6,855	6,852	2,232	2,232
Adj R-Sq	0.8961	0.8961	0.8739	0.8741	0.9297	0.9311
Severe Droughts (excluding mild drought)						
Drought (t)	-18.74	-21.67	-30.00	-12.90	44.01	50.72
	(16.21)	(16.11)	(34.91)	(35.73)	(165.92)	(169.35)
Drought (t-1)	11.13	9.91	-117.81**	-101.74**	-92.21	-129.68
	(21.33)	(23.16)	(51.31)	(51.15)	(216.22)	(218.07)
Drought (t-2)	2.62	4.51	-31.03	-39.11	343.48*	343.60*
	(19.15)	(19.79)	(36.19)	(35.86)	(196.86)	(197.5)
Cons. Drought		14.27		-115.54**		-129.37
		(31.15)		(46.59)		(224.47)
Farmland		-0.67		2.85***		2.67
		(2.05)		(0.94)		(1.84)
Obs	3,945	3,939	6,756	6,753	2,118	2,118
Adj R-Sq	0.8927	0.8927	0.8873	0.8876	0.9349	0.9362

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

Table 2.39: Regression results for Real Total Debt of Dairy Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	**1**	**2**	**1**	**2**	**1**	**2**
All Droughts						
Drought (t)	23.34	22.96	6.45	-0.89	97.46	103.89
	(21.21)	(26.18)	(29.53)	(32.37)	(195.11)	(203.51)
Drought (t-1)	-36.51*	-36.87*	-101.98***	-112.21***	-229.77	-238.56
	(20.25)	(22.18)	(32.26)	(36.24)	(161.93)	(199.63)
Drought (t-2)	-16.70	-16.45	40.04	34.11	70.67	84.36
	(19.27)	(19.33)	(37.69)	(37.38)	(152.03)	(153.07)
Cons. Drought		0.45		10.87		-4.57
		(19.09)		(25.95)		(82.66)
Farmland		0.45		4.22***		1.92
		(1.59)		(1.08)		(1.27)
Obs	4,659	4,650	7,890	7,887	2,436	2,436
Adj R-Sq	0.8746	0.8745	0.8954	0.8959	0.9403	0.9407
Mild Droughts (excluding severe drought)						
Drought (t)	32.10	35.60	8.15	-24.81	14.62	-28.14
	(28.34)	(38.61)	(36.78)	(43.77)	(231.94)	(268.79)
Drought (t-1)	-49.46**	-47.55**	-96.98***	-119.23***	-204.22	-254.58
	(22.39)	(24.11)	(31.88)	(38.12)	(157.29)	(206.73)
Drought (t-2)	-26.52	-26.00	44.74	38.96	127.12	133.53
	(20.58)	(20.51)	(38.65)	(38.49)	(159.07)	(161.6)
Cons. Drought		-4.37		40.00		59.00
		(26.13)		(30.11)		(112.65)
Farmland		0.00		3.99***		1.93
		(1.73)		(1.12)		(1.36)
Obs	3,852	3,849	6,855	6,852	2,232	2,232
Adj R-Sq	0.8765	0.8764	0.8842	0.8846	0.9365	0.937
Severe Droughts (excluding mild drought)						
Drought (t)	-27.35	-31.80	-20.14	-7.29	189.45	200.87
	(21.28)	(23.16)	(35.58)	(36.35)	(239.86)	(245.57)
Drought (t-1)	-66.51**	-70.79**	-180.76***	-170.44***	145.83	129.69
	(26.81)	(28.54)	(52.96)	(53.27)	(309.02)	(305.06)
Drought (t-2)	4.27	5.31	-21.75	-29.58	565.36*	563.07*
	(20.89)	(20.93)	(35.54)	(35.27)	(310.49)	(309.51)
Cons. Drought		24.38		-77.16		-161.52
		(23.12)		(51.21)		(244.01)
Farmland		0.72		4.11***		1.69
		(1.85)		(1.17)		(1.32)
Obs	3,945	3,939	6,756	6,753	2,118	2,118
Adj R-Sq	0.8752	0.8751	0.8959	0.8963	0.9387	0.9391

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

Table 2.40: Regression results for Real Short-term-Debt of Sheep & Beef Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	**1**	**2**	**1**	**2**	**1**	**2**
			All Droughts			
Drought (t)	1.67	1.16	13.81	17.55	74.43	43.44
	(7.88)	(6.81)	(10.52)	(9.99)	(46.39)	(41.44)
Drought (t-1)	-1.48	-2.06	-5.96	-2.03	15.55	-17.88
	(6.65)	(6.03)	(7.41)	(7.78)	(33.69)	(33.06)
Drought (t-2)	5.31	5.27	26.33*	26.48*	71.03	70.51
	(6.71)	(6.69)	(13.33)	(13.33)	(45.97)	(45.53)
Cons. Drought		0.78		-6.23		62.63
		(4.67)		(10.14)		(62.23)
Farmland		-0.03		0.09		0.00
		(0.05)		(0.11)		(0.01)
Obs	9,228	9,216	3,687	3,687	2,739	2,736
Adj R-Sq	0.4735	0.472	0.5127	0.5127	0.662	0.6625
			Mild Droughts (excluding severe drought)			
Drought (t)	-4.66	-8.31	13.09	17.31	89.46*	59.58
	(12.95)	(13.07)	(10.42)	(10.82)	(45.76)	(39.72)
Drought (t-1)	-0.80	-3.57	-9.95	-6.56	-0.17	-22.72
	(5.28)	(5.62)	(8.54)	(8.44)	(33.58)	(34.69)
Drought (t-2)	3.05	3.11	26.57*	26.70*	47.63	48.80
	(6.03)	(6.03)	(13.98)	(13.98)	(47.59)	(47.97)
Cons. Drought		4.65		-6.06		48.69
		(4.11)		(11.93)		(66.21)
Farmland		-0.04		0.09		-0.01
		(0.04)		(0.12)		(0.01)
Obs	8,403	8,391	3,474	3,474	2,613	2,610
Adj R-Sq	0.4429	0.4415	0.5147	0.5146	0.6707	0.6709
			Severe Droughts (excluding mild drought)			
Drought (t)	0.52	-0.08	-23.59	-21.42	-63.58	-63.82
	(11.37)	(11.89)	(15.75)	(15.83)	(70.71)	(71.31)
Drought (t-1)	1.62	1.11	-42.35*	-42.53*	-81.20	-81.29
	(13.94)	(14.42)	(24.96)	(25.06)	(77.95)	(78.08)
Drought (t-2)	16.96	15.96	-12.32	-12.33	-51.54	-51.50
	(10.47)	(10.35)	(16.96)	(17.02)	(40.92)	(40.92)
Cons. Drought		5.06		-34.38		7.90
		(7.37)		(33.31)		(22.43)
Farmland		-0.06		0.09		0.00
		(0.05)		(0.12)		(0.01)
Obs	7,701	7,695	3,204	3,204	2,469	2,466
Adj R-Sq	0.6451	0.6444	0.5139	0.514	0.6786	0.6782

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

Table 2.41: Regression results for Real Long-term-Debt of Sheep & Beef Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	**1**	**2**	**1**	**2**	**1**	**2**
			All Droughts			
Drought (t)	-2.07	-0.48	-7.66	-6.95	-18.40	0.91
	(3.46)	(3.51)	(9.98)	(9.96)	(34.11)	(38.29)
Drought (t-1)	0.05	1.93	-10.42	-9.48	19.52	40.37
	(3.21)	(3.97)	(6.62)	(9.01)	(32.74)	(37.61)
Drought (t-2)	-9.16*	-9.04*	-7.46	-7.51	5.13	5.40
	(4.74)	(4.74)	(14.51)	(14.53)	(39.13)	(39.05)
Cons. Drought		-2.59		-1.78		-39.01
		(4.11)		(10.81)		(34.97)
Farmland		0.09		-0.05		0.01
		(0.07)		(0.07)		(0.03)
Obs	9,228	9,216	3,687	3,687	2,739	2,736
Adj R-Sq	0.9092	0.9092	0.8085	0.8084	0.6123	0.612
			Mild Droughts (excluding severe drought)			
Drought (t)	0.18	3.57	-7.56	-6.29	-17.63	2.69
	(4.82)	(5.08)	(11.82)	(12.04)	(36.13)	(44.93)
Drought (t-1)	-0.14	2.41	-8.84	-7.83	29.56	44.81
	(3.15)	(4.01)	(6.64)	(9.44)	(32.55)	(37.86)
Drought (t-2)	-7.80*	-7.51*	-7.53	-7.58	16.23	15.51
	(4.42)	(4.43)	(15.41)	(15.42)	(40.83)	(40.43)
Cons. Drought		-4.23		-2.25		-33.05
		(4.05)		(10.83)		(38.09)
Farmland		0.12		-0.05		0.00
		(0.07)		(0.07)		(0.02)
Obs	8,403	8,391	3,474	3,474	2,613	2,610
Adj R-Sq	0.9051	0.9052	0.8014	0.8013	0.6039	0.6036
			Severe Droughts (excluding mild drought)			
Drought (t)	-4.46	-4.45	10.21	10.06	9.98	10.29
	(5.21)	(5.43)	(13.16)	(13.44)	(47.21)	(47.62)
Drought (t-1)	-3.39	-3.31	-3.63	-2.83	17.95	18.16
	(7.22)	(7.41)	(23.66)	(23.87)	(59.31)	(59.42)
Drought (t-2)	-2.78	-2.66	11.20	11.02	30.16	30.08
	(6.62)	(6.61)	(15.61)	(15.58)	(44.47)	(44.48)
Cons. Drought		-2.48		-2.14		-7.02
		(4.73)		(5.81)		(16.09)
Farmland		0.12		-0.06		0.00
		(0.07)		(0.08)		(0.03)
Obs	7,701	7,695	3,204	3,204	2,469	2,466
Adj R-Sq	0.9192	0.9193	0.796	0.7959	0.5946	0.5942

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

Table 2.42: Regression results for Real Total Debt of Sheep & Beef Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	**1**	**2**	**1**	**2**	**1**	**2**
			All Droughts			
Drought (t)	-0.59	0.60	2.61	8.99	57.81	45.09
	(8.23)	(7.36)	(13.51)	(12.86)	(46.57)	(55.43)
Drought (t-1)	-2.42	-0.98	-20.49*	-13.54	34.25	20.56
	(6.74)	(7.08)	(10.26)	(11.41)	(40.03)	(48.21)
Drought (t-2)	-4.79	-4.68	18.25	18.39	74.43	74.17
	(6.49)	(6.36)	(14.46)	(14.47)	(52.61)	(52.43)
Cons. Drought		-2.00		-11.42		25.71
		(5.84)		(16.08)		(68.04)
Farmland		0.07		0.06		0.00
		(0.07)		(0.12)		(0.02)
Obs	9,228	9,216	3,687	3,687	2,739	2,736
Adj R-Sq	0.8042	0.8039	0.8106	0.8106	0.6817	0.6815
			Mild Droughts (excluding severe drought)			
Drought (t)	-4.77	-4.84	0.60	8.19	71.94	60.25
	(13.54)	(13.85)	(14.97)	(15.68)	(47.47)	(61.45)
Drought (t-1)	-1.98	-2.07	-22.53**	-16.46	29.16	20.26
	(5.39)	(6.69)	(10.74)	(11.99)	(42.37)	(49.33)
Drought (t-2)	-5.88	-5.51	17.61	17.74	62.29	62.82
	(6.85)	(6.82)	(13.74)	(13.75)	(58.61)	(58.46)
Cons. Drought		0.20		-11.41		19.11
		(5.75)		(17.58)		(74.57)
Farmland		0.10		0.06		-0.01
		(0.07)		(0.12)		(0.02)
Obs	8,403	8,391	3,474	3,474	2,613	2,610
Adj R-Sq	0.8007	0.8005	0.8083	0.8082	0.6744	0.6741
			Severe Droughts (excluding mild drought)			
Drought (t)	-3.85	-4.41	-12.48	-10.31	-50.35	-50.26
	(10.63)	(11.12)	(23.75)	(24.06)	(75.81)	(76.38)
Drought (t-1)	-0.04	-0.43	-43.87	-43.53	-68.65	-68.54
	(13.58)	(14.02)	(35.11)	(35.31)	(76.91)	(77.02)
Drought (t-2)	13.15	12.27	-2.02	-2.14	-23.85	-23.89
	(10.01)	(9.88)	(24.67)	(24.71)	(55.25)	(55.26)
Cons. Drought		1.80		-37.15		-0.42
		(8.76)		(34.16)		(25.05)
Farmland		0.08		0.06		0.00
		(0.07)		(0.12)		(0.03)
Obs	7,701	7,695	3,204	3,204	2,469	2,466
Adj R-Sq	0.8566	0.8566	0.8243	0.8242	0.6647	0.6643

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

Table 2.43: Regression results for Real Total Equity of Dairy Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	**1**	**2**	**1**	**2**	**1**	**2**
All Droughts						
Drought (t)	13.47	-5.51	137.86***	75.05	-9.81	-30.63
	(39.17)	(42.41)	(45.79)	(47.72)	(307.83)	(350.51)
Drought (t-1)	3.67	-13.62	-2.06	-68.91*	-59.40	-86.63
	(42.72)	(48.11)	(40.95)	(36.15)	(248.91)	(307.01)
Drought (t-2)	27.40	23.23	16.86	13.52	39.08	42.57
	(34.02)	(33.73)	(41.84)	(42.21)	(279.81)	(278.76)
Cons. Drought		27.90		109.02**		35.74
		(30.84)		(53.94)		(125.12)
Farmland		-0.20		0.57		0.37
		(2.05)		(0.94)		(1.06)
Obs	4,659	4,650	7,890	7,887	2,436	2,436
Adj R-Sq	0.7955	0.7952	0.9264	0.9265	0.8486	0.8485
Mild Droughts (excluding severe drought)						
Drought (t)	29.56	14.71	145.84**	52.27	-125.43	-170.74
	(51.97)	(60.96)	(62.69)	(58.19)	(381.28)	(478.95)
Drought (t-1)	-0.51	-9.30	-10.20	-67.68*	-140.19	-177.69
	(49.03)	(51.52)	(42.37)	(38.88)	(252.52)	(325.87)
Drought (t-2)	31.80	30.74	14.27	12.01	-13.37	-11.97
	(37.23)	(37.11)	(43.34)	(43.37)	(261.88)	(262.57)
Cons. Drought		19.67		119.25**		57.63
		(39.95)		(58.39)		(165.74)
Farmland		-0.68		0.93		0.48
		(2.61)		(0.95)		(1.12)
Obs	3,852	3,849	6,855	6,852	2,232	2,232
Adj R-Sq	0.7914	0.791	0.9195	0.9195	0.8315	0.8314
Severe Droughts (excluding mild drought)						
Drought (t)	31.04	27.74	77.25*	60.36	29.58	-32.07
	(34.96)	(38.11)	(45.82)	(50.49)	(237.98)	(251.08)
Drought (t-1)	39.66	34.19	-84.15	-104.39*	494.20	420.70
	(61.27)	(64.22)	(56.48)	(57.61)	(366.47)	(373.17)
Drought (t-2)	-45.76	-45.50	-5.54	-1.05	421.72	442.46
	(36.42)	(36.76)	(46.17)	(44.93)	(345.67)	(341.38)
Cons. Drought		29.91		138.25		673.83
		(41.23)		(99.19)		(449.23)
Farmland		0.62		0.71		0.47
		(1.81)		(0.97)		(1.17)
Obs	3,945	3,939	6,756	6,753	2,118	2,118
Adj R-Sq	0.8137	0.8133	0.9453	0.9453	0.8666	0.8666

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

Table 2.44: Regression results for Real Total Profit of Dairy Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	**1**	**2**	**1**	**2**	**1**	**2**
			All Droughts			
Drought (t)	29.95***	14.28*	42.03***	10.79*	-26.39	-70.48**
	(7.17)	(7.76)	(10.16)	(6.18)	(30.41)	(33.87)
Drought (t-1)	1.45	-13.50**	7.71	-24.67***	32.61	-21.13
	(5.42)	(5.49)	(7.62)	(8.24)	(24.77)	(27.21)
Drought (t-2)	-19.29***	-22.09***	-47.27***	-48.40***	-59.92**	-55.91**
	(5.23)	(5.41)	(10.21)	(9.91)	(29.1)	(27.76)
Cons. Drought		25.50***		53.58***		74.19***
		(5.91)		(18.61)		(21.97)
Farmland		-0.13		-0.04		0.31
		(0.25)		(0.13)		(0.24)
Obs	4,659	4,650	7,890	7,887	2,436	2,436
Adj R-Sq	0.2949	0.2991	0.3359	0.342	0.1768	0.1854
			Mild Droughts (excluding severe drought)			
Drought (t)	34.27***	24.09***	58.16***	31.81***	-50.93	-113.60**
	(4.61)	(5.59)	(13.51)	(9.11)	(39.99)	(47.04)
Drought (t-1)	-4.01	-9.92*	-3.51	-19.52**	34.66	-14.22
	(5.35)	(5.88)	(7.48)	(8.51)	(27.14)	(29.22)
Drought (t-2)	-25.96***	-26.81***	-49.48***	-49.73***	-66.60**	-65.68**
	(5.86)	(5.91)	(11.03)	(10.87)	(33.62)	(32.08)
Cons. Drought		13.05***		33.72		78.77***
		(3.41)		(21.76)		(24.18)
Farmland		-0.16		-0.02		0.37
		(0.24)		(0.15)		(0.27)
Obs	3,852	3,849	6,855	6,852	2,232	2,232
Adj R-Sq	0.3847	0.3859	0.3067	0.3086	0.151	0.1624
			Severe Droughts (excluding mild drought)			
Drought (t)	47.71***	41.03***	57.06***	43.54***	76.28**	60.97**
	(10.04)	(8.81)	(9.03)	(6.49)	(34.44)	(27.53)
Drought (t-1)	40.27***	34.17***	51.57***	37.27***	198.87***	177.02***
	(7.67)	(5.61)	(10.13)	(10.29)	(55.29)	(51.19)
Drought (t-2)	-2.43	-0.18	-17.67	-13.18	-23.28	-17.94
	(5.67)	(5.38)	(12.14)	(11.15)	(51.94)	(47.78)
Cons. Drought		43.13		100.17***		162.97
		(35.28)		(31.36)		(165.01)
Farmland		-0.14		0.01		0.33
		(0.29)		(0.15)		(0.26)
Obs	3,945	3,939	6,756	6,753	2,118	2,118
Adj R-Sq	0.2862	0.2886	0.394	0.3989	0.1948	0.203

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

Table 2.45: Regression results for Real Total Interest of Dairy Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	**1**	**2**	**1**	**2**	**1**	**2**
			All Droughts			
Drought (t)	1.96	3.87**	-4.72**	-4.04*	-2.98	-1.86
	(2.01)	(1.93)	(1.92)	(2.22)	(8.19)	(9.38)
Drought (t-1)	1.26	3.10*	-0.74	-0.05	0.78	2.63
	(1.67)	(1.81)	(2.21)	(2.74)	(10.06)	(11.19)
Drought (t-2)	-0.44	-0.09	-2.68	-2.72	-11.23	-11.75
	(1.04)	(1.04)	(2.21)	(2.21)	(8.47)	(8.83)
Cons. Drought		-3.22***		-1.21		-2.08
		(0.97)		(1.66)		(5.31)
Farmland		0.15		0.05		-0.06
		(0.18)		(0.05)		(0.11)
Obs	4,659	4,650	7,890	7,887	2,436	2,436
Adj R-Sq	0.8242	0.8245	0.9087	0.9086	0.9203	0.9205
			Mild Droughts (excluding severe drought)			
Drought (t)	3.40	6.30*	-3.75*	-4.07	2.98	7.72
	(3.02)	(3.24)	(2.21)	(2.61)	(10.34)	(12.37)
Drought (t-1)	1.89	3.61*	0.98	0.76	-0.72	3.50
	(2.07)	(1.93)	(2.39)	(2.91)	(11.81)	(11.81)
Drought (t-2)	-0.22	0.01	-0.65	-0.72	-12.38	-12.63
	(1.06)	(1.07)	(2.21)	(2.19)	(8.75)	(8.78)
Cons. Drought		-3.85***		0.38		-6.12
		(1.34)		(1.82)		(6.62)
Farmland		0.13		0.05		-0.08
		(0.22)		(0.05)		(0.12)
Obs	3,852	3,849	6,855	6,852	2,232	2,232
Adj R-Sq	0.8148	0.8151	0.9053	0.9053	0.9141	0.9144
			Severe Droughts (excluding mild drought)			
Drought (t)	1.91	2.68*	-1.51	-0.01	-14.64	-14.78
	(1.41)	(1.51)	(2.51)	(2.44)	(11.01)	(10.58)
Drought (t-1)	4.34***	5.08***	-2.32	-0.77	-19.03	-18.14
	(1.38)	(1.47)	(4.43)	(4.47)	(24.91)	(22.25)
Drought (t-2)	0.03	-0.24	-0.77	-1.30	18.25	18.25
	(1.22)	(1.22)	(3.05)	(2.97)	(19.46)	(19.83)
Cons. Drought		-5.29***		-10.94***		2.86
		(1.43)		(3.77)		(12.74)
Farmland		0.03		0.03		-0.06
		(0.09)		(0.06)		(0.12)
Obs	3,945	3,939	6,756	6,753	2,118	2,118
Adj R-Sq	0.8832	0.8834	0.9108	0.9108	0.9152	0.9153

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

Table 2.46: Regression results for Real Total Equity of Sheep & Beef Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	**1**	**2**	**1**	**2**	**1**	**2**
			All Droughts			
Drought (t)	18.09	7.33	19.00	7.30	77.26	78.39
	(14.29)	(14.41)	(29.96)	(33.46)	(70.97)	(75.96)
Drought (t-1)	-0.04	-11.26	-12.10	-28.38	78.33	80.74
	(11.98)	(14.65)	(86.03)	(111.35)	(58.43)	(51.49)
Drought (t-2)	2.35	3.53	26.36	27.74	60.44	57.95
	(13.81)	(13.65)	(54.62)	(53.77)	(70.81)	(70.51)
Cons. Drought		15.81		32.33		-2.01
		(10.01)		(55.03)		(81.87)
Farmland		-0.65**		1.18		0.17
		(0.31)		(1.21)		(0.11)
Obs	9,228	9,216	3,687	3,687	2,739	2,736
Adj R-Sq	0.7595	0.7602	0.9841	0.9842	0.9586	0.9589
			Mild Droughts (excluding severe drought)			
Drought (t)	44.50**	40.81*	40.19	32.56	95.35	97.91
	(20.25)	(21.07)	(40.75)	(42.61)	(79.51)	(92.48)
Drought (t-1)	-12.95	-14.01	-24.41	-30.19	86.05	91.31*
	(12.36)	(14.99)	(96.54)	(115.31)	(51.52)	(52.45)
Drought (t-2)	14.22	14.38	20.52	21.81	83.75	80.84
	(15.31)	(15.21)	(57.75)	(56.89)	(76.82)	(76.98)
Cons. Drought		2.16		18.43		-6.65
		(9.75)		(54.25)		(81.81)
Farmland		-0.64*		1.19		0.17
		(0.33)		(1.27)		(0.11)
Obs	8,403	8,391	3,474	3,474	2,613	2,610
Adj R-Sq	0.7542	0.7549	0.9844	0.9844	0.9457	0.9461
			Severe Droughts (excluding mild drought)			
Drought (t)	-33.83**	-33.25**	-65.87	-62.55	42.32	46.55
	(15.95)	(16.45)	(55.41)	(57.36)	(86.31)	(87.31)
Drought (t-1)	-47.29**	-47.35**	-21.16	-43.84	-227.38	-221.60
	(21.39)	(21.78)	(62.66)	(65.89)	(195.81)	(196.11)
Drought (t-2)	-7.19	-6.87	120.24	125.45	-86.88	-88.79
	(20.51)	(20.53)	(118.97)	(122.18)	(85.53)	(85.89)
Cons. Drought		8.62		71.74		10.84
		(22.61)		(46.82)		(28.76)
Farmland		-0.64*		1.57		0.17*
		(0.33)		(1.68)		(0.11)
Obs	7,701	7,695	3,204	3,204	2,469	2,466
Adj R-Sq	0.7724	0.7725	0.9787	0.9789	0.9597	0.96

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

Table 2.47: Regression results for Real Total Profit of Sheep & Beef Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	**Small Farm**		**Medium Farm**		**Large Farm**	
Model	**1**	**2**	**1**	**2**	**1**	**2**
All Droughts						
Drought (t)	2.62	4.55	-31.20	-21.89	-14.42*	-13.13
	(3.96)	(6.02)	(23.79)	(16.02)	(8.61)	(8.51)
Drought (t-1)	-4.06	-1.82	-6.83	1.56	11.96	13.41
	(3.51)	(1.67)	(10.18)	(4.95)	(8.11)	(8.11)
Drought (t-2)	-0.80	-1.18	13.50	14.53	-11.54	-11.62
	(2.31)	(2.52)	(18.32)	(19.61)	(9.37)	(9.42)
Cons. Drought		-3.24		-10.95		-2.60
		(3.82)		(8.94)		(8.75)
Farmland		-0.06		0.74		0.01
		(0.04)		(0.82)		(0.01)
Obs	9,228	9,216	3,687	3,687	2,739	2,736
Adj R-Sq	0.0733	0.0733	0.2782	0.2843	0.8917	0.8918
Mild Droughts (excluding severe drought)						
Drought (t)	5.17	9.50	-35.30	-26.44	-10.89	-6.40
	(6.51)	(11.01)	(28.44)	(21.88)	(10.24)	(11.02)
Drought (t-1)	-5.71	-2.36	-7.50	-0.24	7.61	11.12
	(4.83)	(1.88)	(8.87)	(4.88)	(8.21)	(8.25)
Drought (t-2)	0.24	-0.08	15.36	16.30	-14.96	-15.25
	(1.35)	(1.41)	(19.78)	(21.06)	(9.77)	(9.83)
Cons. Drought		-5.60		-9.38		-7.40
		(6.04)		(7.43)		(8.91)
Farmland		-0.06		0.78		0.01
		(0.04)		(0.87)		(0.01)
Obs	8,403	8,391	3,474	3,474	2,613	2,610
Adj R-Sq	0.0684	0.0685	0.2714	0.2779	0.4512	0.4517
Severe Droughts (excluding mild drought)						
Drought (t)	-2.96	-3.02	1.46	4.14	-31.75***	-31.38***
	(2.11)	(2.17)	(27.84)	(29.98)	(9.64)	(9.72)
Drought (t-1)	-4.37	-4.48	58.82	53.27	8.11	8.45
	(3.24)	(3.26)	(85.71)	(79.07)	(14.85)	(14.81)
Drought (t-2)	-3.64*	-3.65*	77.50	78.74	-8.43	-8.55
	(2.14)	(2.13)	(102.32)	(103.41)	(8.41)	(8.43)
Cons. Drought		2.34		-12.91		-5.02
		(2.11)		(9.05)		(3.12)
Farmland		-0.07		0.45		0.01
		(0.04)		(0.51)		(0.01)
Obs	7,701	7,695	3,204	3,204	2,469	2,466
Adj R-Sq	0.4542	0.4555	0.4491	0.451	0.9023	0.9024

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

Table 2.48: Regression results for Real Total Interest of Sheep & Beef Farming by sizes using NZDI as drought indicator (NZD in 000)

Indicators	Small Farm		Medium Farm		Large Farm	
Model	**1**	**2**	**1**	**2**	**1**	**2**
All Droughts						
Drought (t)	-0.26	-0.29	-0.64	-0.36	-0.01	1.15
	(0.21)	(0.24)	(0.42)	(0.58)	(1.92)	(2.41)
Drought (t-1)	0.16	0.15	-0.40	-0.13	2.16	3.41
	(0.23)	(0.28)	(0.51)	(0.77)	(2.28)	(2.94)
Drought (t-2)	-0.17	-0.13	-0.08	-0.06	2.17	2.19
	(0.21)	(0.21)	(0.71)	(0.71)	(1.81)	(1.81)
Cons. Drought		0.00		-0.39		-2.35
		(0.15)		(0.61)		(2.122)
Farmland		0.02*		0.01		0.00
		(0.01)		(0.01)		(0.01)
Obs	9,228	9,216	3,687	3,687	2,739	2,736
Adj R-Sq	0.8782	0.8797	0.7325	0.7329	0.8987	0.8988
Mild Droughts (excluding severe drought)						
Drought (t)	-0.26	-0.25	-1.13**	-1.04	-0.52	0.58
	(0.22)	(0.29)	(0.44)	(0.68)	(2.05)	(2.91)
Drought (t-1)	0.13	0.12	-0.07	0.01	2.98	3.80
	(0.24)	(0.31)	(0.49)	(0.75)	(2.31)	(2.96)
Drought (t-2)	-0.20	-0.14	-0.17	-0.16	2.47	2.44
	(0.19)	(0.19)	(0.64)	(0.64)	(1.87)	(1.87)
Cons. Drought		-0.01		-0.08		-1.80
		(0.17)		(0.71)		(2.39)
Farmland		0.02*		0.01		0.00
		(0.01)		(0.01)		(0.01)
Obs	8,403	8,391	3,474	3,474	2,613	2,610
Adj R-Sq	0.8752	0.8767	0.7231	0.7234	0.897	0.8971
Severe Droughts (excluding mild drought)						
Drought (t)	-0.50*	-0.52**	1.44	1.54	2.30	2.32
	(0.25)	(0.26)	(1.37)	(1.41)	(2.41)	(2.43)
Drought (t-1)	-0.28	-0.29	0.17	0.00	1.71	1.72
	(0.78)	(0.77)	(1.55)	(1.56)	(5.09)	(5.09)
Drought (t-2)	-0.19	-0.19	0.05	0.09	2.29	2.29
	(0.67)	(0.67)	(1.14)	(1.14)	(2.57)	(2.57)
Cons. Drought		0.16		-0.68		-0.60
		(0.32)		(0.55)		(0.73)
Farmland		0.02*		0.01*		0.00
		(0.01)		(0.01)		(0.01)
Obs	7,701	7,695	3,204	3,204	2,469	2,466
Adj R-Sq	0.8682	0.8682	0.7165	0.7169	0.8994	0.8994

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

Alternative model - with additional first difference variables:

To address the temporal auto-correlation in the residuals per farm. We used an alternative model with additional exogenous factors defined as follows:

$$Y_{it} = \alpha + \delta_0 D_{it} + \delta_1 D_{i,t-1} + \delta_2 D_{i,t-2} + \delta_3 \Delta A_{it} + \delta_4 \Delta Y_{it} + c_i + u_{it} \text{ .... \textbf{Model 3}}$$

$$Y_{it} = \alpha + \delta_0 D_{it} + \delta_1 D_{i,t-1} + \delta_2 D_{i,t-2} + \delta_3 CD_{it} + \delta_4 \Delta A_{it} + \delta_5 \Delta Y_{it} + c_i + u_{it} \text{ .... \textbf{Model 4}}$$

Where, Y_{it} is the farm financing choices measures - real short-term debt, real long-term debt, real total debt, farm equity, and related financial measures (profit, and interest payments) - of farm i at time t. D_{it} is the binary variable indicating drought conditions computed through NZPGI for farm i at time t, using the thresholds described above. ΔA_{it} is the linear first difference of real total assets of farm i at time t as a control variable. ΔY_{it} is the linear first difference of the farm financing choices measures of farm i at time t as an additional exogenous factor. The farm fixed effects c_i accounts for any unobserved and time-invariant farm heterogeneity that may influence farm debts and may be correlated with current and past drought conditions. u_{it} is an iid error term representing unobserved factors that change over time and affect Y_{it}.

In our second model 4, we add a variable, CD_{it} that measures if there were consecutive droughts (over more than one summer season).

The results are presented below in Table ***2.49*** to Table ***2.52***. The results are statistically significant and show the same effect on dairy and sheep/beef farm financing choices as from Models 1 and 2.

Table 2.49: Regression results for Debt of Dairy Farming using the first differenced variables model (NZD in 000)

Indicators	**Real Short-term-Debt**		**Real Long-term-Debt**		**Real Total Debt**	
Model	(3)	(4)	(3)	(4)	(3)	(4)
All Droughts						
Drought (t)	26.06* (15.22)	24.90 (15.32)	13.44 (28.46)	21.00 (29.36)	35.64 (31.25)	41.85 (31.94)
Drought (t-1)	40.99** (16.13)	40.08** (16.27)	69.42** (27.54)	75.33*** (28.26)	100.77*** (31.84)	105.62*** (32.23)
Drought (t-2)	70.44*** (18.29)	69.59*** (18.10)	92.94*** (33.37)	98.40*** (33.52)	158.05*** (37.56)	162.53*** (37.41)
Cons. Drought		-1.57 (3.40)		10.15* (5.22)		8.34 (6.11)
Δ total assets	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Δ Y	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
Obs	23,364	23,364	23,364	23,364	23,364	23,364
Adj R-Sq	0.553	0.553	0.8036	0.8036	0.8107	0.8108
Mild Droughts (excluding severe drought)						
Drought (t)	20.42 (15.97)	16.67 (16.07)	-8.92 (30.98)	-0.54 (31.94)	8.16 (34.28)	12.64 (34.98)
Drought (t-1)	41.23** (17.15)	37.35** (17.44)	63.78** (29.94)	72.46** (30.96)	92.08*** (34.94)	96.71*** (35.41)
Drought (t-2)	68.32*** (19.58)	65.31*** (19.30)	95.46** (37.60)	102.20*** (37.85)	156.04*** (42.50)	159.64*** (42.30)
Cons. Drought		-4.75 (3.26)		10.61* (5.77)		5.66 (6.55)
Δ total assets	0.000 (0.000)	0.000 (0.000)	0.000* (0.000)	0.000* (0.000)	0.000* (0.000)	0.000* (0.000)
Δ Y	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
Obs	21,486	21,486	21,486	21,486	21,486	21,486
Adj R-Sq	0.5214	0.5215	0.8025	0.8025	0.8083	0.8083
Severe Droughts (excluding mild drought)						
Drought (t)	66.53** (28.22)	67.91** (28.13)	151.89** (61.57)	134.71** (61.87)	197.60*** (73.60)	182.88** (74.30)
Drought (t-1)	52.94** (25.04)	48.95* (26.98)	42.78 (33.22)	92.45*** (32.84)	93.88** (45.97)	136.50*** (45.34)
Drought (t-2)	81.07*** (25.05)	78.22*** (26.55)	147.09*** (43.16)	182.57*** (42.92)	232.10*** (52.70)	262.54*** (53.14)
Cons. Drought		-1.63 (3.17)		20.24*** (6.35)		17.37** (6.70)
Δ total assets	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Δ Y	0.000*** (0.000)	0.000*** (0.000)	0.000** (0.000)	0.000** (0.000)	0.000** (0.000)	0.000** (0.000)
Obs	14,826	14,826	14,826	14,826	14,826	14,826
Adj R-Sq	0.5616	0.5616	0.8224	0.8226	0.8283	0.8284

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

Table 2.50: Regression results for Debt of Sheep/Beef Farming using the first differenced variables model (NZD in 000)

Indicators	**Real Short-term-Debt**		**Real Long-term-Debt**		**Real Total Debt**	
Model	(3)	(4)	(3)	(4)	(3)	(4)
All Droughts						
Drought (t)	8.47**	9.32**	0.37	4.67	13.36**	18.38***
	(3.78)	(3.86)	(3.81)	(4.11)	(5.57)	(5.85)
Drought (t-1)	13.14***	13.85***	0.93	4.50	11.34*	15.51**
	(3.93)	(4.05)	(5.03)	(4.98)	(6.57)	(6.63)
Drought (t-2)	13.31***	13.94***	-2.55	0.62	9.51	13.22*
	(4.56)	(4.65)	(6.02)	(5.81)	(7.74)	(7.61)
Cons. Drought		1.50		7.53**		8.80**
		(1.23)		(3.56)		(3.69)
Δ total assets	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Δ Y	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Obs	24,801	24,801	24,801	24,801	24,801	24,801
Adj R-Sq	0.7287	0.7287	0.7528	0.7533	0.7966	0.7969
Mild Droughts (excluding severe drought)						
Drought (t)	8.72**	9.14**	-0.65	3.78	12.76**	17.52***
	(3.84)	(3.93)	(4.04)	(4.16)	(5.76)	(6.00)
Drought (t-1)	13.88***	14.35***	0.78	5.79	11.44*	16.82**
	(4.04)	(4.26)	(5.14)	(4.96)	(6.84)	(6.89)
Drought (t-2)	12.66***	13.02***	-3.08	0.62	8.64	12.62
	(4.71)	(4.85)	(6.25)	(5.87)	(8.02)	(7.77)
Cons. Drought		0.67		7.02**		7.54**
		(1.19)		(3.15)		(3.34)
Δ total assets	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Δ Y	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Obs	22,845	22,845	22,845	22,845	22,845	22,845
Adj R-Sq	0.6989	0.6989	0.747	0.7474	0.7708	0.7711
Severe Droughts (excluding mild drought)						
Drought (t)	8.68	8.06	12.28	1.84	19.53	8.01
	(7.95)	(7.90)	(11.69)	(12.50)	(15.25)	(15.95)
Drought (t-1)	12.67**	13.86**	-8.63	11.34	5.64	27.66***
	(4.90)	(5.82)	(6.39)	(8.92)	(7.36)	(10.49)
Drought (t-2)	18.53***	19.35***	-6.65	7.19	11.28	26.54***
	(5.16)	(5.40)	(6.68)	(7.30)	(8.34)	(9.09)
Cons. Drought		0.52		8.82*		9.72**
		(1.46)		(4.56)		(4.92)
Δ total assets	0.000*	0.000*	0.000	0.000	0.000**	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Δ Y	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Obs	15,111	15,111	15,111	15,111	15,111	15,111
Adj R-Sq	0.7679	0.7679	0.7268	0.7275	0.7912	0.7917

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

Table 2.51: Regression results for other financials of Dairy Farming using the first differenced variables model (NZD in 000)

Indicators	**Real Total Equity**		**Real Total Profit**		**Real Interest Paid**	
Model	(3)	(4)	(3)	(4)	(3)	(4)
All Droughts						
Drought (t)	131.74*** (33.70)	140.71*** (34.05)	9.51*** (2.58)	8.21*** (2.64)	0.74 (1.57)	1.65 (1.63)
Drought (t-1)	168.88*** (35.66)	175.88*** (36.04)	-11.72*** (2.97)	-12.76*** (3.00)	4.34** (1.72)	5.05*** (1.73)
Drought (t-2)	130.07*** (33.21)	136.55*** (33.55)	-18.70*** (2.87)	-19.64*** (2.87)	3.37 (2.39)	4.02* (2.35)
Cons. Drought		12.03 (7.52)		-1.77*** (0.57)		1.22*** (0.38)
Δ total assets	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Δ Y	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
Obs	23,364	23,364	23,364	23,364	23,364	23,364
Adj R-Sq	0.7591	0.7591	0.5932	0.5935	0.8453	0.8454
Mild Droughts (excluding severe drought)						
Drought (t)	114.73*** (34.66)	124.43*** (34.99)	7.12** (2.86)	5.72** (2.86)	0.33 (1.75)	1.44 (1.82)
Drought (t-1)	203.86*** (37.26)	213.91*** (37.67)	-9.10*** (3.14)	-10.57*** (3.22)	4.44** (1.83)	5.59*** (1.85)
Drought (t-2)	152.87*** (36.72)	160.67*** (37.14)	-18.96*** (3.09)	-20.10*** (3.09)	3.44 (2.63)	4.33* (2.58)
Cons. Drought		12.28* (7.33)		-1.80*** (0.56)		1.40*** (0.42)
Δ total assets	0.000* (0.000)	0.000** (0.000)	0.000 (0.000)	0.000 (0.000)	0.000* (0.000)	0.000* (0.000)
Δ Y	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
Obs	21,486	21,486	21,486	21,486	21,486	21,486
Adj R-Sq	0.7527	0.7528	0.5759	0.5762	0.8408	0.841
Severe Droughts (excluding mild drought)						
Drought (t)	231.52*** (87.84)	208.03** (88.84)	20.42*** (7.36)	21.54*** (7.35)	4.24 (3.55)	2.71 (3.59)
Drought (t-1)	169.68*** (46.63)	237.56*** (47.86)	-4.56 (3.86)	-7.73* (4.08)	0.54 (3.13)	4.96 (3.13)
Drought (t-2)	247.53*** (52.05)	296.02*** (54.23)	-17.68*** (3.91)	-19.94*** (4.05)	5.51 (3.69)	8.66** (3.72)
Cons. Drought		27.66*** (8.42)		-1.29** (0.65)		1.80*** (0.48)
Δ total assets	0.000** (0.000)	0.000** (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Δ Y	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
Obs	14,826	14,826	14,826	14,826	14,826	14,826
Adj R-Sq	0.8906	0.8908	0.6149	0.615	0.8265	0.8268

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

Table 2.52: Regression results for other financials of Sheep/Beef Farming using the first differenced variables model (NZD in 000)

Indicators	**Real Total Equity**		**Real Total Profit**		**Real Interest Paid**	
Model	(1)	(2)	(1)	(2)	(1)	(2)
			All Droughts			
Drought (t)	20.21 (22.33)	20.38 (20.62)	4.32 (4.34)	4.02 (4.21)	-0.01 (0.23)	0.10 (0.26)
Drought (t-1)	22.47 (27.32)	22.62 (25.71)	1.18 (2.97)	0.93 (2.84)	0.11 (0.27)	0.20 (0.29)
Drought (t-2)	31.59 (27.83)	31.72 (26.20)	1.07 (1.11)	0.85 (1.07)	-0.21 (0.26)	-0.13 (0.27)
Cons. Drought		0.31 (6.91)		-0.53 (0.50)		0.19 (0.19)
Δ total assets	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Δ Y	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
Obs	24,801	24,801	24,801	24,801	24,801	24,801
Adj R-Sq	0.8049	0.8049	0.5325	0.5325	0.7887	0.7887
			Mild Droughts (excluding severe drought)			
Drought (t)	21.43 (23.35)	20.89 (21.09)	4.52 (4.60)	4.12 (4.43)	-0.03 (0.24)	0.11 (0.26)
Drought (t-1)	25.11 (28.98)	24.51 (26.32)	1.68 (3.07)	1.22 (2.85)	0.04 (0.26)	0.20 (0.28)
Drought (t-2)	37.45 (29.46)	37.00 (27.20)	1.12 (1.16)	0.79 (1.09)	-0.21 (0.27)	-0.10 (0.28)
Cons. Drought		-0.85 (6.84)		-0.64 (0.50)		0.21 (0.14)
Δ total assets	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Δ Y	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
Obs	22,845	22,845	22,845	22,845	22,845	22,845
Adj R-Sq	0.8014	0.8014.	0.5316	0.5316	0.8027	0.8028
			Severe Droughts (excluding mild drought)			
Drought (t)	-28.43 (30.22)	-41.00 (30.52)	-5.98 (5.39)	-6.61 (5.44)	0.47 (0.66)	0.25 (0.71)
Drought (t-1)	64.25 (52.77)	88.33* (46.07)	7.56 (5.99)	8.77 (6.48)	-0.41 (0.33)	0.01 (0.65)
Drought (t-2)	55.15 (36.95)	71.82** (31.91)	-0.26 (1.62)	0.58 (1.48)	-0.09 (0.34)	0.20 (0.51)
Cons. Drought		10.63 (7.34)		0.53 (0.53)		0.18 (0.25)
Δ total assets	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000* (0.000)	0.000* (0.000)
Δ Y	0.000*** (0.000)	0.000*** (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Obs	15,111	15,111	15,111	15,111	15,111	15,111
Adj R-Sq	0.783	0.783	0.2911	0.2911	0.7828	0.7829

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

Chapter 3: **Impact of Droughts on Banks' Non-Performing Loans: A Study of Banks' Agricultural Loan Portfolios**

Abstract

The combination of climate change that is changing the likelihoods and intensities of droughts, a large heavily indebted agricultural sector, and financial institutions which are liable to crises provide a potentially volatile intersection of concerns. This chapter empirically tests the relationships between droughts (as measured by the New Zealand Pasture Growth Index-NZPGI) and banks' agricultural non-performing loans (NPLs) (loans overdue by 90 days or more) at the regional level. Using panel data fixed-effects regression modelling, this estimation combines data from the National Institute of Water and Atmospheric Research Ltd (NIWA), the Reserve Bank of New Zealand (RBNZ), and Federated Farmers' farming surveys. Our results show a statistically significant positive impact of droughts on dairy farming NPLs. However, we find no significant impact of droughts on sheep/beef farming NPLs. We then evaluate the implications of these findings for policymakers and the banking sector.

3.1 Introduction

Are the banking sector's balance sheets at risk from climate change? In New Zealand, climate change is predicted to increase the intensity and frequency of droughts in some of the main agricultural areas. Here, we investigate the recent historical record to identify the relation between droughts and non-performing loans held by New Zealand banks during and after drought events in the last two decades. Ultimately, this investigation is motivated by the concern that any erosion in the quality of banks' loan portfolios may become a cause for systemic problems in the banking sector.

In the banking literature, non-performing loans (NPLs) are defined as un-paid loans outstanding for more than 90 days (Louzis, Vouldis, & Metaxas, 2012; Manz, 2019). The literature has identified various factors that lead to the non-performance of such loans. First, macroeconomic factors (such as disposable income, unemployment, monetary conditions, industrial production, and GDP) have a substantial impact on NPLs (Cifter, Yilmazer, & Cifter, 2009; Ghosh, 2015; Rinaldi & Sanchis-Arellano, 2006; Salas & Saurina, 2002; Vazquez, Tabak, & Souto, 2012). Second, microeconomic factors (such as low-cost efficiency, high measured efficiency, low capitalization, leverage, and performance) have also been found to have an impact on NPLs (Berger & DeYoung, 1997; Breuer, 2006; Louzis et al., 2012; Podpiera & Weill, 2008; Salas & Saurina, 2002).

While extensively exploring macroeconomic, and microeconomic variables as the antecedents of NPLs, existing research generally does not take into account the potential role of weather and climate variables as determinants of NPLs, although emerging empirical evidence shows that difficult natural conditions adversely impact business, specifically agricultural farm business (Edwards, Gray, & Hunter, 2009; Escalante, Song, & Dodson, 2016; Lawes & Kingwell, 2012; Tran, Stoeckl, Esparon, & Jarvis, 2016). We start to fill this gap by proposing and testing the impact of droughts on banks' NPLs in New Zealand.

Most previous studies focused on sectoral aggregate NPLs, apart from studies by Louzis et al. (2012) and Vazquez et al. (2012) who studied the antecedents of NPLs in different loan categories (consumer loans, business loans, mortgages, household loans, and corporate loans). This literature provides evidence that microeconomic and macroeconomic factors that effects NPLs vary between different loan categories (Ghosh, 2017). Consequently, we chose to focus on agricultural NPLs at a disaggregated level – separating NPLs associated with dairy farming, and separately with sheep and beef farms.

Further, limited prior research has explored the association between climate change and the credit risk of banks. The results have been mixed with studies finding an increase in the cost of debt (e.g., Javadi & Masum, 2021), banks failing to account for flood risk when valuing the refinancing of mortgage (e.g., Garbarino & Guin, 2021) banks restructuring their assets in response to an increase in loan demand following natural disasters (Bos, Li, & Sanders, 2022; Cortés & Strahan, 2017). We aim to extend this stream of research.

Therefore, the present study aims to contribute to the literature in two ways. The first is by examining drought as an additional determinant of NPLs other than the micro and macroeconomic factors across New Zealand banks' two main agricultural loan categories: dairy, sheep and beef farming.[8] The second is by extending the limited line of research inquiry by exploring the quantitative assessment of the effect of climate physical risk on the banks' credit risk by specifically studying the potential impact of droughts on banks' agricultural (dairy, sheep and beef) NPLs. Our focus is on the New Zealand banking system, and we study the potential impact of drought, through farm/agricultural debt, on banking stability. We have

[8] As of September 2021, dairy exposures were 77% of Common Equity Tier 1 (CET1 capital is a part of a bank's capital. It includes paid up ordinary share capital, retained earnings, and certain accounting reserves) and sheep/beef was 31% (RBNZ, 2021a, 2021b)

reasons to believe that droughts may affect NPLs because droughts can impact the farmers' loan repayment ability (Escalante et al., 2016).

Droughts are measured at the regional level by the latest and improved version of the New Zealand Pasture Growth Index (NZPGI). Using panel data fixed-effects regression modelling, this study examines drought and weather data from the National Institute of Water and Atmospheric Research Ltd (NIWA), banks' balance sheet data from the Reserve Bank of New Zealand (RBNZ), and information on farms operations from Federated Farmers banking surveys to test our model.

The remainder of the chapter is organized as follows: Section 3.2 provides a background of the literature on determinants of NPLs and business risks arising from difficult natural conditions to identify the missing link between the two streams of research that we aim to connect. Sections 3.3, 3.4, 3.5, and 3.6 describe data, drought conditions at dairy and sheep/beef farms, NPLs of dairy and sheep/beef farms, and the estimated model, respectively. We provide results and discussion, and robustness checks, in sections 3.7 and 3.8 separately. The last section concludes.

3.2 Literature background

Climate risk refers to the potential impacts of climate change on various aspects of the economy, including financial stability, economic growth, and business operations. Climate risk has become increasingly relevant to the financial sector, as banks and other financial institutions support the transition to a low-carbon economy (Battiston, Mandel, Monasterolo, Schütze, & Visentin, 2017). The banking sector is particularly exposed to climate risk because it provides financing for various activities that contribute to greenhouse gas emissions, and because its assets, and especially its long-term loans, are vulnerable to the impacts of climate change, such as sea-level rise and increased frequency of extreme weather events (Calvet, Gianfrate, & Uppal, 2022).

There has been growing interest in the policy and academic literature on the role of banks in managing and mitigating both the physical and transition risks that are associated with climate change (Battiston et al., 2017; Campiglio et al., 2018; Nguyen, Diaz-Rainey, Kuruppuarachchi, McCarten, & Tan, 2023). This includes developing methodologies for integrating climate risk into bank risk management frameworks, and designing the regulatory and market-based incentives for banks to invest in low-carbon and climate-resilient activities, and investigating banks' exposure to transition risks (Campiglio et al., 2018; Nguyen et al., 2023). There has been less research exploring the impact of physical climate risk on financial institutions and financial stability.

Literature on the impact of climate shocks on banks is limited (Battiston, Dafermos, & Monasterolo, 2021). With few recent sets of studies exploring whether climate change could increase the credit risk of banks (Battiston, Dafermos, & Monasterolo, 2021; Bos et al., 2022; Cortés & Strahan, 2017; Garbarino & Guin, 2021; Javadi & Masum, 2021). For example, Javadi and Masum (2021) utilizing the Palmer Drought Severity Index (PDSI) as a climate risk measure and loan data originated between 1986 and 2017 in the USA uncovered solid empirical evidence showing that businesses in areas more vulnerable to climate change pay much higher spreads on bank loans. Garbarino and Guin (2021) investigating how banks reacted to a severe flood event in England in 2013–2014 found that in determining the level of interest rates and the amount of credit provided, banks did not ex-post consider flood risk when valuing the refinancing of mortgages.

Cortés and Strahan (2017) and Bos et al. (2022) analysed hazard lending and discovered that banks' asset structures changed in response to an increase in loan demand following natural catastrophes in a statistically and economically meaningful way. Further, Bos et al. (2022) utilized model simulations to predict and quantify the potential impact of climate change on the asset portfolios and profitability of banks in different scenarios. and found climate change reduces banks' ability to lend to profitable investments and decreases banks' capital adequacy, which lowers investment and has a negative impact on financial stability.

In recent years, there has been increasing pressure on financial entities to disclose information on the risks that climate change poses to their operations and investments (XRB, 2022). Many have started to report on their climate risks, often in response to regulations such as those proposed by the Task Force on Climate-related Financial Disclosures (TCFD) (FMA, 2022). The Reserve Bank of New Zealand has highlighted the importance of disclosing the potential financial impacts of climate change and has encouraged financial institutions to adopt consistent and comparable reporting practices. New Zealand's major banks and insurance companies have begun to disclose the extent to which their lending and investment portfolios are exposed to climate risk and have set targets for reducing their carbon footprints (RBNZ, 2022).

Prior research has investigated macroeconomic and microeconomic variables as antecedents of NPLs and has used either a single category of potential determinants or combined the macroeconomic and microeconomic conditions as potential determinants (Manz, 2019).

While focusing on macroeconomic factors as a single category of potential determinants of NPLs, Rinaldi and Sanchis-Arellano (2006) analyzed household NPLs for a panel of European countries and provided empirical evidence that macroeconomic factors such as disposable income, unemployment, and monetary conditions have a strong impact on NPLs. Similarly,

Cifter et al. (2009) investigated the relationship between industrial production and non-performing loans ratio cycle by wavelet network analysis in Turkey over the period January 2001 to November 2007 and found that industrial production cycles affect the sectoral credit-default cycles at different time scales between 2 and 64 months. Vazquez et al. (2012) explored a database that follows the evolution of bad debts of 78 banks in Brazil from the first quarter of 2001 to the first quarter of 2009. They found that banks with large exposures to highly procyclical types of credit tend to suffer a significant worsening in the quality of their credit portfolios in a period of economic downturn. Dinterman, Katchova, and Harris (2018) found that unemployment and interest rate contributed to the financial failures of farms in the US over a twenty-year study period.

Some studies found microeconomic factors such as cost efficiency, bank capitalization, and corporate governance have impacts on NPLs. Berger and DeYoung (1997) studied a sample of US commercial banks from 1985-1994 and found that decreases in measured cost efficiency led to increased future problem loans. Podpiera and Weill (2008) examined the relationship between efficiency and bad loans in the Czech banking industry from 1994-2005. Similarly, they found that decreased cost-efficiency increased future NPLs. More recently, Chaibi (2016) applied quantitative and qualitative proxies to study NPLs and found that cost inefficiency and bank profitability impact credit risk and bank loan quality. Breuer (2006) examined the influence of various institutional variables (banking, legal, political, sociological, and economic institutions) on NPLs and found that a variety of institution characteristics impact the share of non-performing bank assets.

Further, some studies focused on combining both microeconomic and macroeconomic factors that have a significant impact on NPLs. For example, Salas and Saurina (2002) combined macroeconomic and microeconomic variables to explain aggregate NPLs of Spanish Commercial and Savings Banks for the period 1985–1997. They focused on the antecedents of NPLs for commercial and savings banks and found that microeconomic variables such as governance, bank growth policy and solvency can serve as early warning indicators for future changes in NPLs. Later, Konstantakis, Michaelides, and Vouldis (2016) found both macroeconomic and financial factors such as public debt, unemployment and domestic credit, have a certain impact on NPLs in Greece from the period 2001–2015 by applying Vector Autoregressive (VAR) and Vector Error Correction (VEC) modelling approaches. Another recent study by Radivojević et al. (2019) analyzed both macro and micro variables as the determinant of NPLs in the countries of Latin America and found no statistically significant relationship between micro variables and NPLs.

There are very few studies that have explored the issue of NPLs at a sectoral-disaggregated level. Louzis et al. (2012) and Vazquez et al. (2012) studied the antecedents of NPLs in the different loan categories (consumer loans, business loans, mortgages, household, and corporate loans). More recently, Ghosh (2017) analyzed the macroeconomic determinants and impacts of sector-specific NPLs in the US Banking system and found that certain sector-specific NPLs are more sensitive to the various bank balance sheet and macroeconomic factors as compared with aggregate NPLs.

Prior research on farms' balance sheets shows that difficult natural conditions have detrimental effects on borrowing farms' chances of survival and their loan payment ability. For example, Escalante et al. (2016) analyzed the repayment records of farms in the Midwestern and South-Eastern farming regions in the US. Using a split population duration model, they found that the severity of drought conditions adversely impacted borrowing farms' probability of survival and borrower standing. Tran et al. (2016) found that drought-affected properties earn revenues from on-farm production[9] about half as much as other 'similar' properties in Northern Australia. Previously, Lawes and Kingwell (2012), examining 123 farms in an Australian rain-fed agricultural region from 2004 to 2009, found that droughts negatively affected some business indicators (business equity, operating profit/ha, return on capital, and the debt-to-income ratio) of the Australian farms they studied. Edwards et al. (2009) found that droughts negatively impacted farmers' agricultural production in Australia. Hong, Li, and Xu (2019) found

[9] Value of on-farm production, calculated as: live-weight gain for beef cattle multiplied by average price per kilo of beef + other agricultural revenues + non-agricultural revenues (Tran et al., 2016)

evidence of stock markets under-pricing climate risks from drought. They used the Palmer Drought Severity Index and food companies' share price data from thirty-one countries to investigate market efficiency.

However, despite this progress, the level of detail and quality of climate risk disclosures by financial institutions varies widely, and is likely not enough to fully address the challenges posed by climate change. More stringent climate physical risk assessment may be needed.

In this study, we aim to extend the line of research inquiry by exploring the quantitative assessment of the effect of climate physical risk on the banks' credit risk. We do so by specifically studying the potential impact of droughts (as a climate risk measure) on banks' agricultural (dairy, sheep and beef) NPLs.

3.3 Data

3.3.1 Non-Performing Loans Identification Approach

If a loan is impaired or a borrower has not made scheduled repayments on their loan for more than 90 days, it is classified as a non-performing loan (NPL)[10]. The 90 days threshold is widely accepted to define NPLs (Konstantakis et al., 2016; Manz, 2019; Rinaldi & Sanchis-Arellano, 2006).

We use two sources of datasets, RBNZ and Federated Farmers Surveys, for our dependent and control variables (see Table ***3.1***). The data from RBNZ is a quarterly panel of all locally incorporated and registered banks in New Zealand. Our focus is on banks that are engaged in agricultural sector lending; these banks hold 92 per cent of the total assets of the banking system in New Zealand (Reserve Bank of New Zealand, 2020). We obtain data from each bank's balance sheet and profit and loss statement as these are reported to the RBNZ. Apart from that

[10] However, some loan categories, such as consumer loans, the non-repayment period required to classify a loan as non-performing is 180 days.

essential information, the RBNZ collects a statistical monthly survey and bank balance sheet survey from each bank that contains further detailed financial reporting.

We use the following set of information from these RBNZ surveys:

- Asset quality: The total agriculture lending to dairy farms, and sheep/beef farms, which are overdue by 90 days or more, and are thus classified as non-performing loans.
- Bank size and solvency ratios.
- Bank efficiency ratios and return on equity (ROE).

We extract and combine the information from the various surveys to compute our key variables listed in Table ***3.1***.

Table 3.1: List of variables and definitions

Variables	**Definitions**	**Data Source**
Non-performing loans	The total agricultural lending in the sub-sectors of dairy and sheep/beef is overdue by 90 days or more, classified as non-performing loans distributed at the regional level.	RBNZ, and Federated Farm Surveys
Drought	The no. of climate grid stations shows the NZPGI ≤ 30 for consecutively 10 or more days	NIWA
Severe drought	The no. of climate grid stations shows the NZPGI ≤ 20 for consecutively 20 or more days	NIWA
Return on equity (ROE)	Profit after tax as a percentage of average equity over the quarter	RBNZ
Solvency ratio	The ratio of total capital to total risk-weighted assets (RWAs).	RBNZ
Efficiency Ratio	The ratio of the bank's operating income to operating expenses.	RBNZ
Bank Size	Size in terms of banks' total assets compared to total banking assets	RBNZ

We aggregate the droughts' impacted locations of dairy and sheep/beef farming identified by the NZPGI at the regional level. Unfortuantely, the bank-level NPLs data was only available at national level. To match the NPLs data with drought measure at the regional level , we used a Federated Farmers' survey data to compute weights and thus impute the total agriculture sub-sectoral NPLs of each bank for each region. Our study is unique in that NPLs are estimated at the disaggregated individual bank-regional level based on farm survey data on farm location, bank pressure[11], and individual bank relationship[12], instead of branch locations in drought-affected areas. Our approach allows for the possibility that banks' customers and branches are not located in the same region. Specifically, with modern digital banking services, there are not necessarily clear geographical boundaries to bank-customer relationships.[13]

The Federated Farmers' survey data is available from 2017 to 2020, collected in May and November each year. The average sample size of each survey is around 1000 farms. The survey gathers information about farmers' principal business activity, regional location, individual bank connections, loan amount, and perception of banking pressure. We assume that farmers who report being under pressure from their banks are likely having financial difficulty in repaying their bank loans. Therefore, we use the bank pressure responses as a proxy to estimate the bank's NPLs portfolio by region. We calculate the percentage of farmers in a given region who report facing banking pressure and who have a relationship with each bank, over time. We define the percentage as the number of dairy or sheep/beef borrowers from bank "A" in a particular region who faced banking pressure out of total dairy or sheep/beef farmers who borrow from the same bank "A" and faced banking pressure in all regions, at the same time. We used those percentages as weights to distribute each bank's aggregate NPLs at the regional level.

This gives us quarterly estimates of dairy and sheep/beef NPLs of five banks distributed over sixteen New Zealand regions from Mar-2017 to Jun-2020.

3.3.2 DROUGHTS IDENTIFICATION APPROACH

[11] In each survey the farmers are asked question if they feel any undue pressure from their bank. The undue pressure question combines pressure from mortgages and overdrafts.

[12] The farmers corresponding banks for their mortgages and overdrafts.

[13] The banks' customers location is not available for our research.

Droughts are the most common hydro-meteorological disasters where economic damage lasts for months or years. The severity and occurrence frequency are the tools often used to identify droughts (Yevjevich, 1967).

To measure drought, we use the NZPGI developed and maintained by NIWA. The index considers radiative energy, soil moisture, and temperature to measure grass growth. These are the critical measuring factors of droughts. The NZPGI data is available daily for each virtual climate station network (VCSN). There are 11,491 nodes of the VCSN – which is an approximately 5km grid covering the whole of New Zealand. The NZPGI values correspond to the amount of grass expected to grow in a "normal" hectare of farmland in a unit of kg of dry matter per hectare per day; a lower value indicates less grass growth. A prolonged period of dryness during the summer season from December to April can indicate drought conditions and affect grass growth. Therefore, we use the NZPGI values from the summer season as a drought indicator.

The NZPGI had not previously been used for drought identification, and consequently, no threshold for this purpose has previously been defined. We identify two different drought thresholds using the index's values and the frequency of occurrence, measured in days per location. The first threshold is defined as drought if the NZPGI ≤ 30 consecutively for at least ten days. Similarly, under the second threshold measure, a severe drought condition is defined if the NZPGI ≤ 20 for consecutively 20 or more days. We compute the regional level drought data separately based on dairy or sheep/beef farm locations in a given region. To identify the VCSN locations for dairy and sheep/beef farms, we use the meshblock information of each dairy and sheep/beef farm from stats NZ agriculture production surveys. Each farm is assumed to be located in the centroid of its respective meshblock and is then linked to the records from its nearest VCSN grid point. Finally, we aggregate the number of grid stations in a region that was affected by drought conditions, conditional on dairy or sheep/beef farms being located there. Therefore, the definition of a regional drought can be different for dairy farms, and sheep/beef farms. We combine these with data on the number of regional grid stations of dairy and sheep/beef farms under drought and severe drought conditions for each year from 2015 to 2020.

3.4 Drought conditions at dairy and sheep/beef farms:

Drought is a phenomenon linked to excessive dry periods and a shortage of water supply and soil moisture (Nagarajan, 2009). The escalation in drought intensity and frequency can be a big concern for any economy. According to the Global drought risk index 2020, by country, New Zealand is more prone to droughts among the top dairy and sheep/beef export countries (Germany, Netherland, Belgium, Ireland, and the United Kingdom: see Table ***3.9*** in section 3.11 Appendix) (IEP, 2020). On average every year three or more regions are affected by droughts (NIWA, 2021). The drought in the year 2020 was similar to the one in 2013 for some parts of the country which was the worst in 40 years (NIWA, 2020).

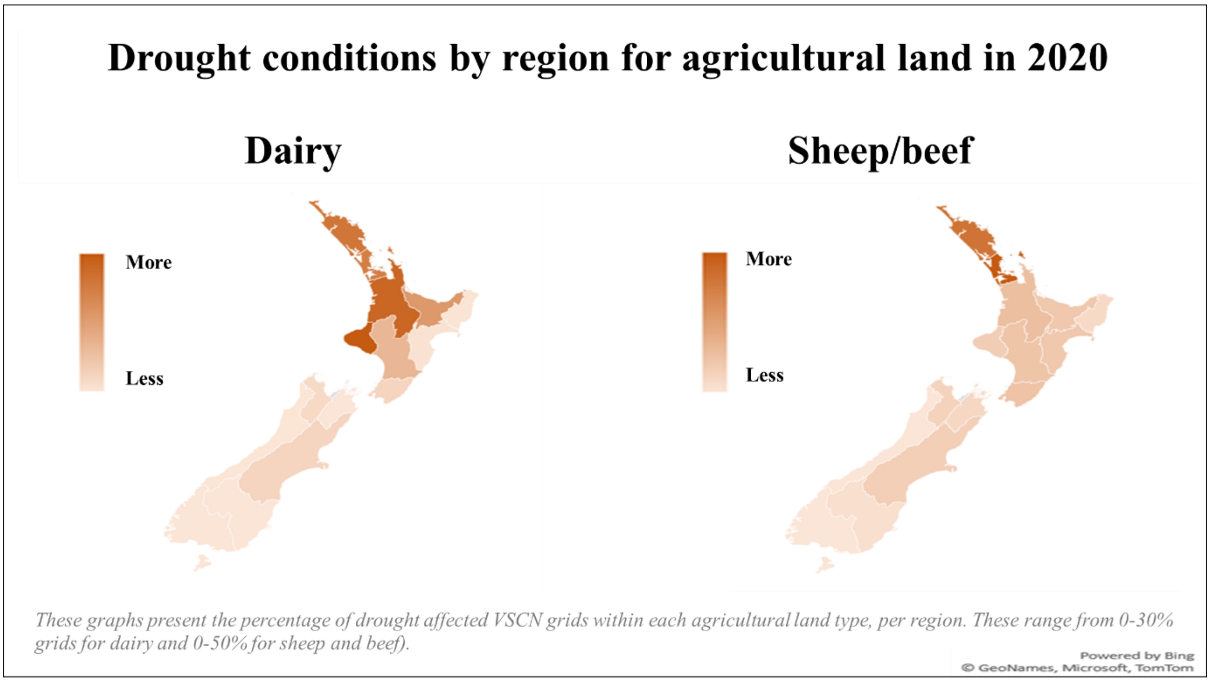

Figure 3.1: Drought conditions at regional dairy and sheep/beef farmlands in 2020

Figure ***3.1*** compares the prevalence of NZPGI-based drought conditions of the year 2020, the most recent and widespread drought-affected year for our study period, at dairy farmlands and sheep/beef farmlands[14]. The maps show the percentage of VCSN locations affected by drought conditions in a region conditional on dairy or sheep/beef farms being located there. The spread of drought conditions shows the most affected regions for each sector in the year 2020.

Consistent with (NIWA, 2020) findings our analysis shows that the Waikato region was most affected by droughts in dairy farmlands, and Northland was the region most affected by droughts for sheep/beef farmlands in the year 2020. About 30 per cent of the land in the Waikato region under dairy farmland was affected by droughts in the year 2020, and about 50 per cent of the land in the Auckland and Northland regions under sheep/beef farmland was affected by droughts that year. Similarly, our analysis in Figure ***3.2*** shows on average dairy farmlands in the Waikato region were most hit by droughts over the years 2006-2020 and sheep/beef farmlands in the Auckland and the Northland regions were most affected by drought over the same period.

[14] The farmlands covered by dairy and sheep/beef in New Zealand are shown in Table ***3.10*** (in section 3.11 Appendix)

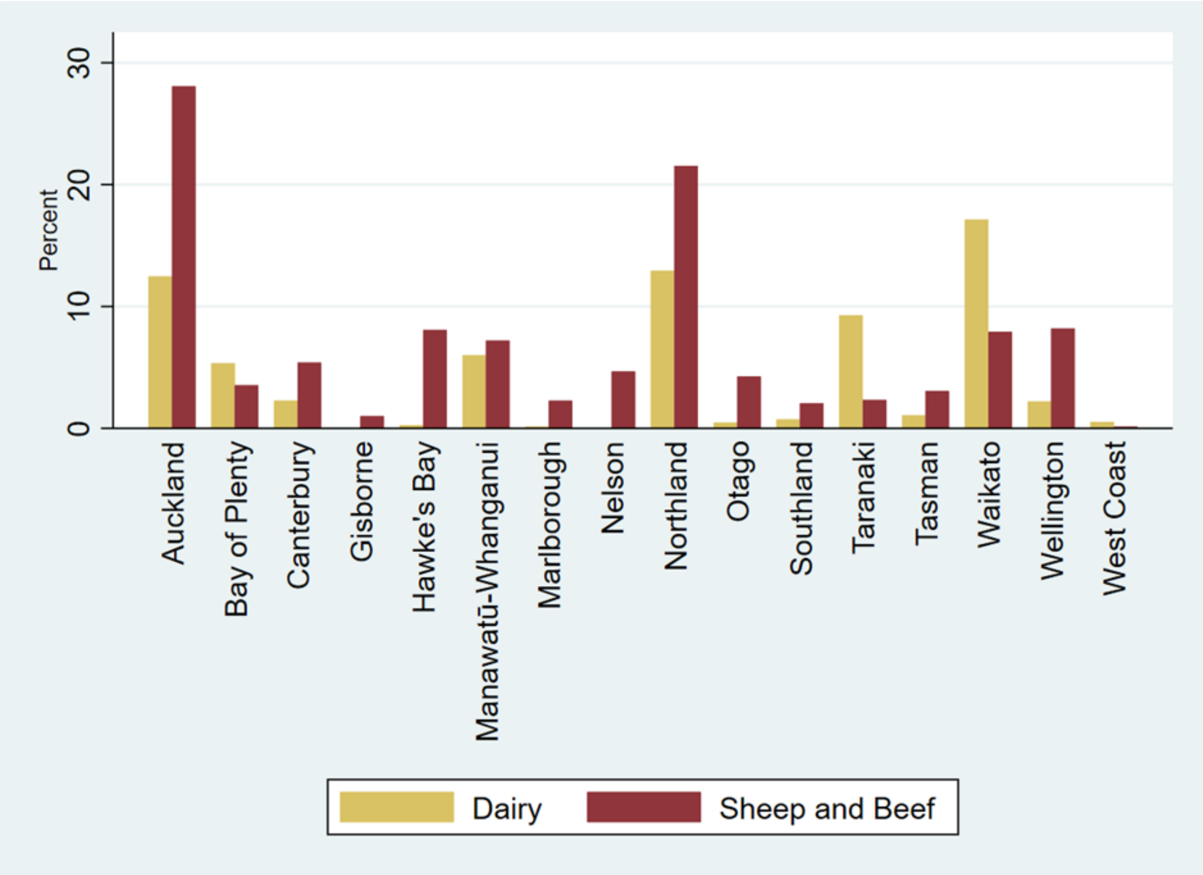

Figure 3.2: The average percentage of all land, dairy, and sheep and beef farmlands at the regional level affected by drought conditions (averaged over the years 2006-2020)

Our analysis in Figure ***3.3*** shows the years 2013, 2015, and 2020 have shown more widespread drought conditions in different areas of dairy and sheep/beef farmland. The droughts in the years 2013 and 2020 are comparable in terms of severity (NIWA, 2020).

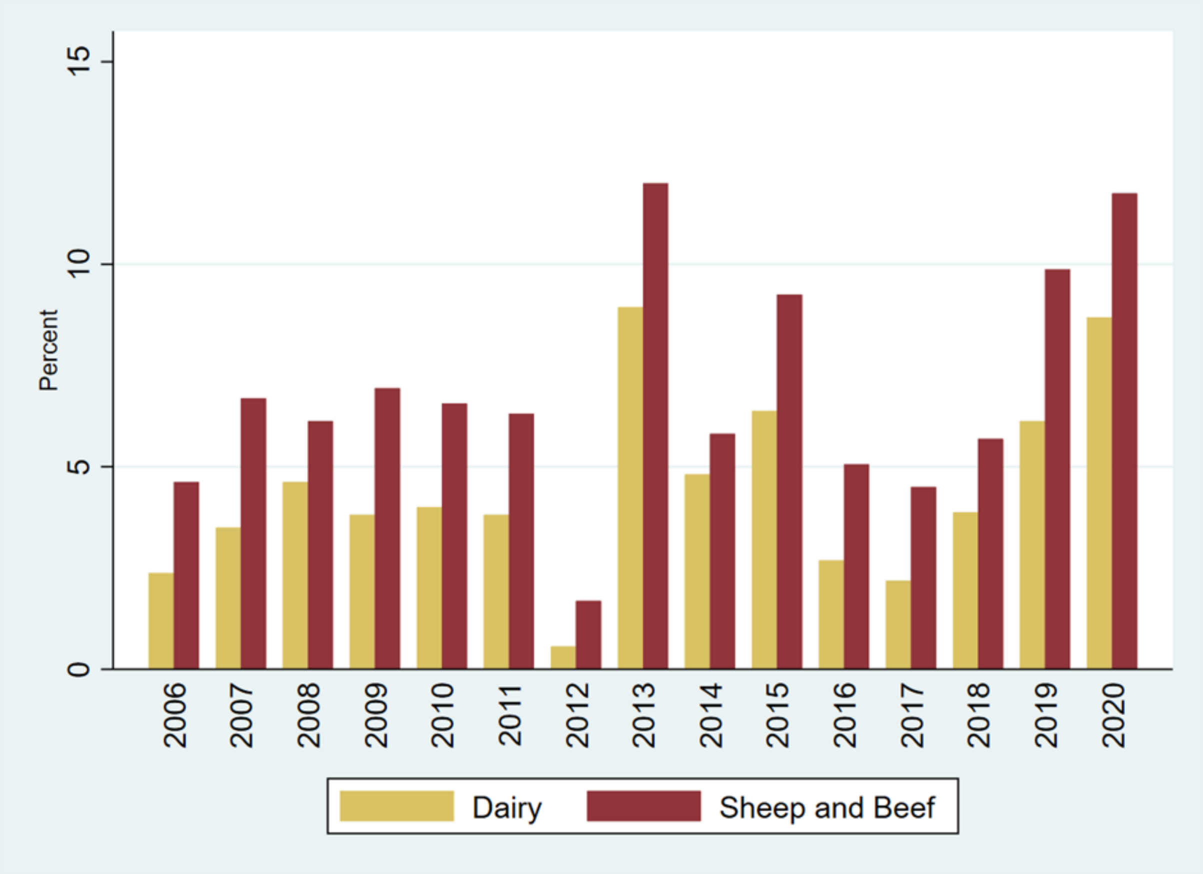

Figure 3.3: The average percentage of all land, dairy, and sheep and beef farms affected by drought conditions over the years 2006-2020 (averaged at the regional level)

3.5 Non-Performing Loans – Dairy and Sheep/beef

From 2016 to 2020 agricultural sector NPLs increased from 0.9 per cent to 2.1 per cent of outstanding agricultural loans, compared with an increase from 0.5 per cent to 0.76 per cent for banks' total loans across sectors during the same period (RBNZ, 2021c). The breakdown of agriculture sector NPLs into dairy and non-dairy provides further insights. Each sector has its own operational and financial characteristics. Dairy cattle consume more pasture than sheep and beef cattle, and the operational cost and the profit margin of dairy are greater than sheep and beef (Copland & Stevens, 2012). The recent financial performance of both sectors reported by Statistics NZ confirms higher profitability[15] and use of assets[16] for dairy farms (see Table ***3.6*** in section 3.11 Appendix). However, on average the dairy sector also relies more on debt, and some dairy farms are highly indebted. For these reasons, the impact of droughts on NPLs can be expected to differ between sectors. In Figure ***3.4*** we compare the dairy and non-dairy agricultural sector NPLs over time. There is an upward trend in dairy NPLs since 2016 when the data begin. Our focus is on agricultural NPLs as our dependent variable, estimating the impact of drought conditions on NPLs in the dairy and sheep/beef sectors separately.

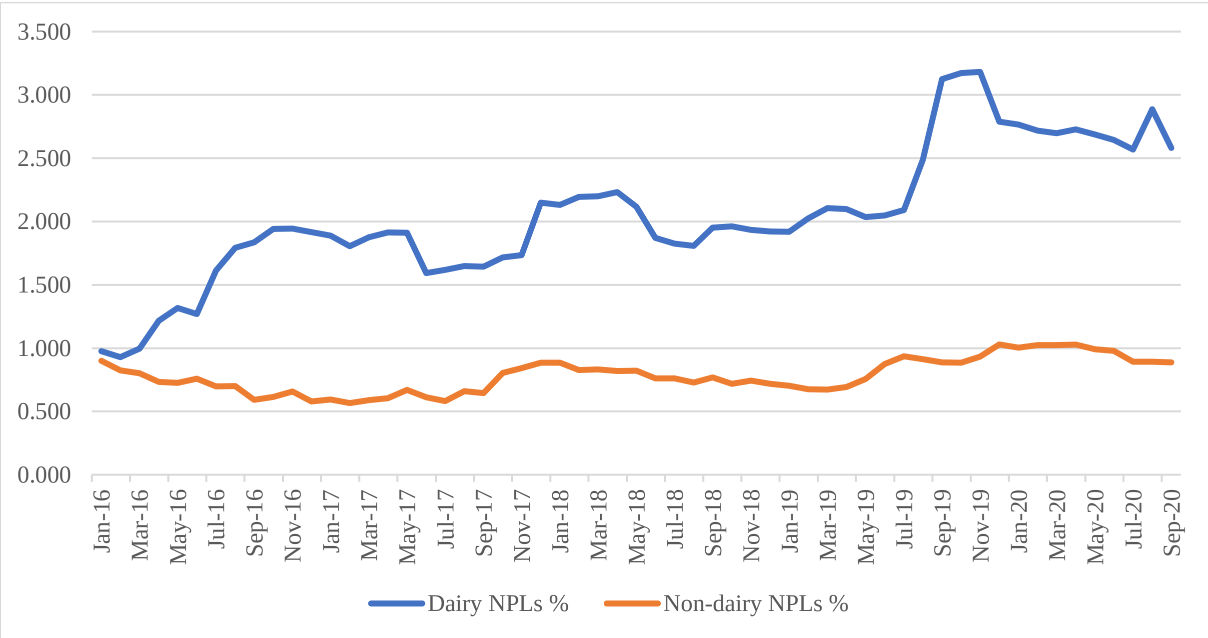

Figure 3.4: Non-Performing Loans by Sector (% of Total Loans) (Data Source: RBNZ)

Our estimates of dairy NPLs across banks distributed at the regional level are presented in Figure ***3.5***. While regions such as Waikato where the dairy industry is concentrated account for the greatest proportions of dairy NPLs, the distribution and timing also show some correlation with droughts. For example, in 2018 the Southland region shows more dairy

[15] dairy reported 4.5billion NZD more profit than sheep/beef in the year 2020

[16] dairy owns 16.6 billion NZD more value of assets than sheep/beef in the year 2020

NPLs than other regions whereas in 2019 and 2020 the Waikato region shows the most dairy NPLs. These are the same years that these regions experienced droughts. Gisborne and Nelson are estimated to have practically no dairy NPLs, and these same regions show no signs of droughts for dairy land as shown in Figure ***3.2***.

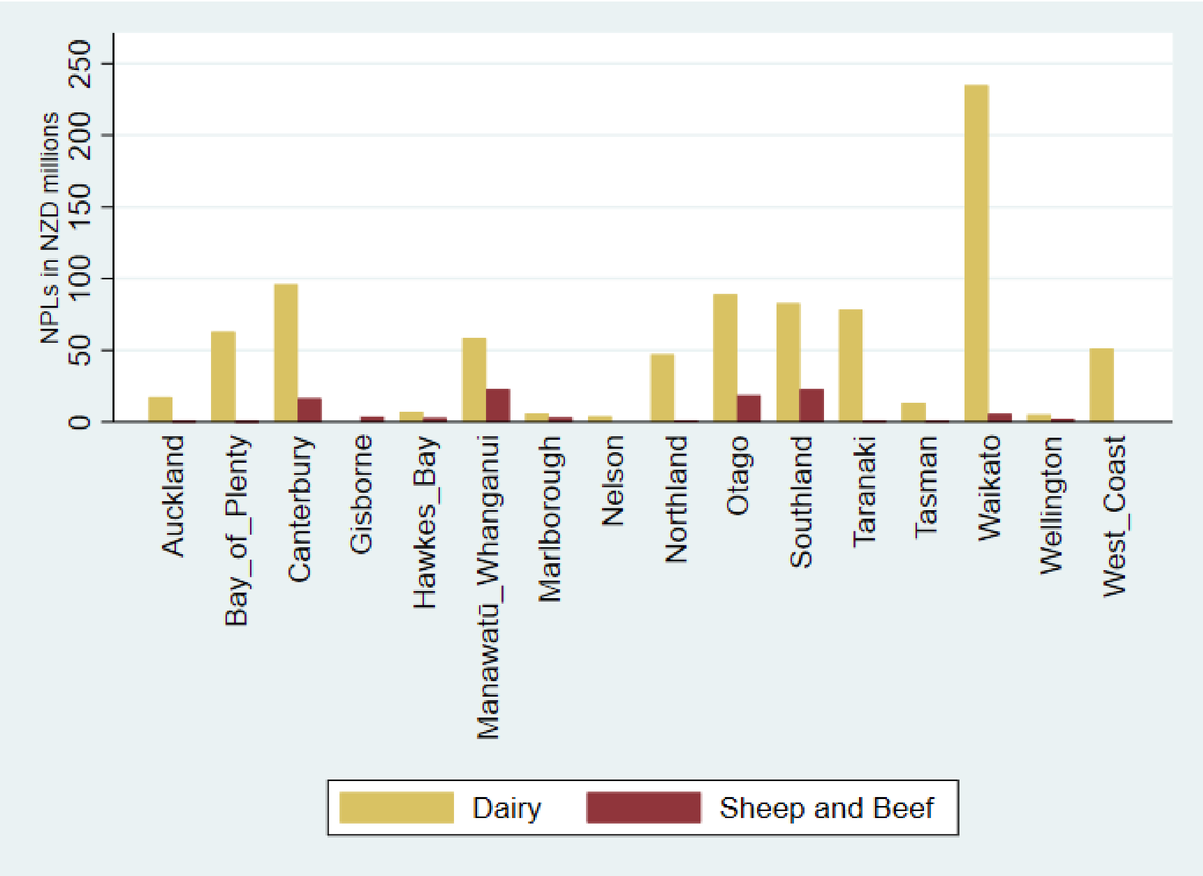

Figure 3.5: The average dairy and sheep and beef sector Non-Performing Loans of all banks at the regional level (averaged over the years 2017-2020) (Data Source: RBNZ & Federated Farm Surveys)

The bulk of sheep/beef NPLs are estimated to be in the Manawatu-Whanganui, Canterbury, Otago, and Southland regions, whereas on average most of the sheep/beef farmlands in Auckland and Northland are affected by droughts. Figure ***3.6*** shows an increasing trend for both dairy and sheep/beef NPLs and illustrates that dairy NPLs are much higher than sheep/beef NPLs. The latter reflects both the greater size of the dairy sector and the dairy sector’s greater reliance on debt financing.

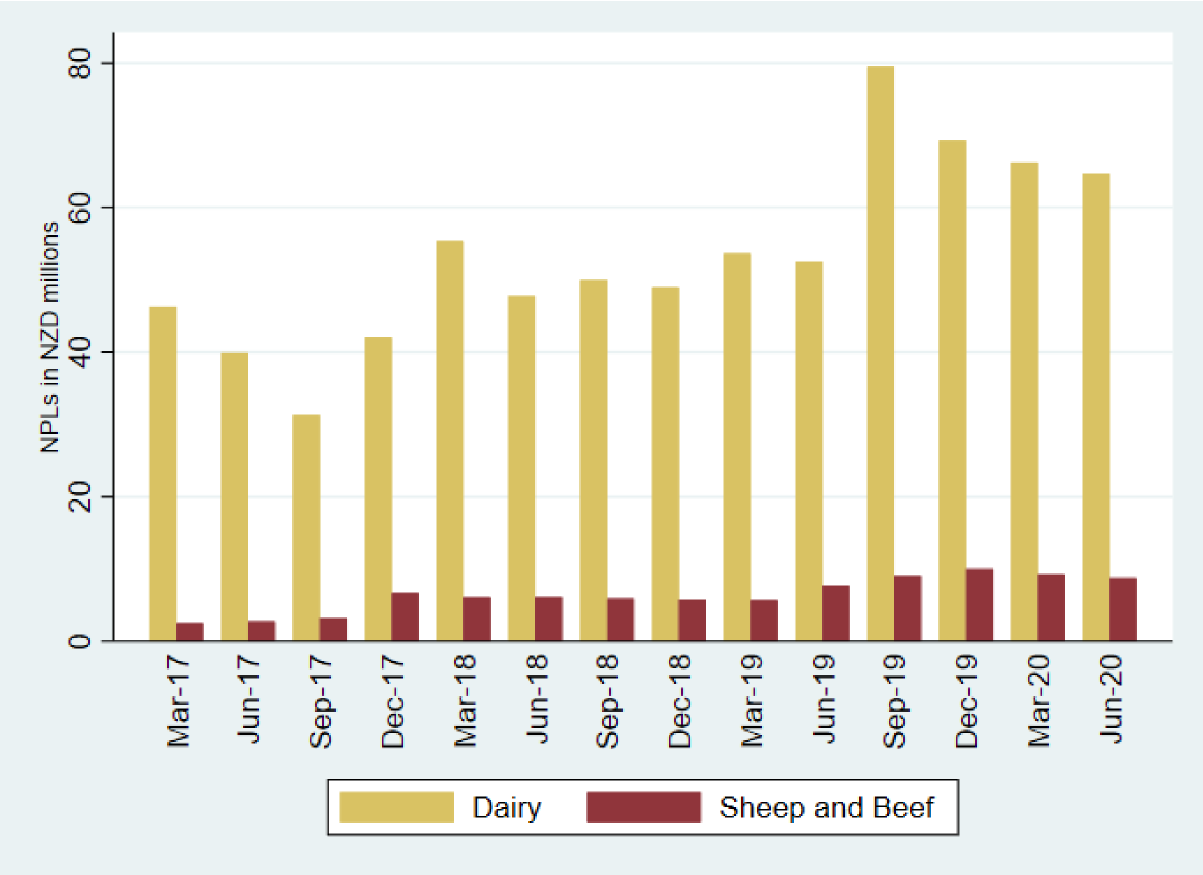

Figure 3.6: The average dairy and sheep and beef sector Non-Performing Loans of all banks over the years 2017-2020 (averaged at the regional level) (Data Source: RBNZ & Federated Farm Surveys)

3.6 Model

The estimation model is designed to evaluate whether drought conditions affect banks' NPLs in the dairy and sheep/beef sectors, both of which are pasture-reliant in New Zealand. We do this with a pasture-growth-based definition of drought conditions using the NZPGI. Let x be a dairy farm borrower of bank i with the farm located in region j and identified as '0' if the borrower reports no banking stress and '1' if reporting banking stress in time t. So, the weight computation w of bank i for NPLs in region j at time t is:

$$w_{i,j,t} = \frac{\sum x_{i,j,t}}{\sum x_{i,t}} \times 100 \qquad (1)$$

We then multiply computed weights by aggregate NPLs of bank i at time t to estimate the part of the aggregate attributable to region j:

$$NPL_{i,j,t} = w_{i,j,t} \times NPL_{i,t} \qquad (2)$$

Let v be the VCSN linked to the nearest dairy farmer k located in region j, identified as '0' if the station shows no drought condition and '1' if it shows drought conditions in time t. So, the computation of drought for dairy in region j at time t is:

$$D_{j,t} = \sum v_{k,j,t} \qquad (3)$$

Following the literature in panel data studies in the same context (Dinterman et al., 2018; Pourzand, Noy, & Sağlam, 2020), we use a fixed-effects OLS estimation approach to model drought effects on NPLs. The fixed-effects model removes the time-invariant characteristics to assess the net effects of droughts on NPLs. The panel data model is:

$$NPL_{i,j,t} = \sum_{m=0}^{4} \beta_m D_{j,t-m} + \gamma X_{i,t} + \varepsilon_{i,j} + \mu_t + u_{i,t} \qquad (4)$$

$NPL_{i,j,t}$ is the non-performing loans to dairy or sheep/beef sector loans for bank i in the region j at time t. $D_{j,t-m}$ are the drought conditions, identified by the NZPGI threshold, for dairy or sheep/beef farms in region j at time t to $t-4$. We include four-quarter lags for drought effects that can be identified over a year. Furthermore, the non-payment of debts takes 90 days to be recognized as NPLs; we, therefore, assume the effect of drought on NPLs will take time to appear in the banks' records. $X_{i,t}$ are the observable bank-specific variables as defined in Table ***3.1*** to control for microeconomic factors as determinants of NPLs. Whereas $\varepsilon_{i,j}$ are the unobservable bank-region-specific effects, μ_t are the time fixed-effects and $u_{i,t}$ is the error term.

3.7 Results and discussion

The primary statistical characteristics of banks and both dairy and sheep/beef sectors are presented in Table ***3.2*** and Table ***3.3*** respectively. It includes data from five New Zealand banks mainly engaged in agricultural sector lending across sixteen regions of the country. Average regional NPLs are higher for the dairy sector, at 10.68 million dollars when compared to sheep/beef's average NPLs of 1.28 million dollars. The average bank size in terms of total assets is 18.27 per cent covering the principal banking sector of New Zealand. The banks' average return on equity performance ratio is relatively high at 12.03 per cent. Banks' solvency as measured by the average capital adequacy ratio is 13.80 per cent, well in excess of regulatory requirements. The banks are performing efficiently, generating 2.05 times more operating income than operating expenses on average.

Table 3.2: Descriptive Statistics of Banks

Variables	Observations	Mean	Standard Deviation
Bank Size	1,760	18.27	9.61
Bank Performance (ROE)	1,760	12.03	3.59
Bank Solvency (Capital Ratio)	1,760	13.80	1.14
Bank Efficiency (Op Income- Op Exp Ratio)	1,760	2.05	0.22
No. of Banks (n)	5	Time (t)	12 Q

Data Source: RBNZ

Table 3.3: Descriptive Statistics of dairy, sheep & beef farming

Variables	Dairy Farming			Sheep/Beef Farming		
	Observations	Mean	Standard Deviation	Observations	Mean	Standard Deviation
NPLs at Region	1,120	10.68	21.51	1,120	1.28	5.38
Drought (Grid Stations)	1,760	8.82	31.14	1,760	11.98	32.40
Severe Drought (Grid Stations)	1,760	2.85	18.32	1,760	3.74	15.97
No. of Banks (n)	5	Time (t)	12 Q	5	Time (t)	12 Q

Data Source: RBNZ

On average, nine dairy land grid stations in a given region show drought conditions at a given time, and around three grid stations show severe drought conditions. For sheep/beef land use areas an average of over 12 grid stations in a given region show drought conditions, and four grid stations show severe drought conditions.

Our primary focus remains on droughts and NPLs, but we control for other microeconomic and macroeconomic factors by including time and bank-region fixed-effects. The regression results for the impact of droughts on dairy NPLs are presented in Table ***3.4***. We found a significant increase in dairy NPLs that lasted for three quarters, starting from the first quarter following to occurrence of the drought event. We tested our model for only drought conditions as an explanatory variable in the first two columns with bank-region fixed effects and without controlling for time-variant bank-specific variables. However, in column 2, we applied both bank-region and time fixed-effects as well. To rigorously test our model, we further controlled for time-variant bank-specific variables along with bank-region fixed effects in columns 3 and 4, and in column 4 we additionally applied the time fixed effects as well. None of these differences in specification made any significant difference to the coefficients of our main variables of interest.

Table 3.4: Regression results for Droughts and NPLs of Dairy Farming

Indicators	**Total Dairy NPLs**			
	(1)	**(2)**	**(3)**	**(4)**
Droughts (NZPGI≤30 and consecutive days≥10)				
Drought (t)	0.06 (0.04)	0.04 (0.04)	0.05 (0.04)	0.04 (0.04)
Drought (t-1)	**0.10**** **(0.04)**	**0.08*** **(0.04)**	**0.09**** **(0.04)**	**0.08*** **(0.04)**
Drought (t-2)	**0.19***** **(0.05)**	**0.18***** **(0.05)**	**0.18***** **(0.05)**	**0.18***** **(0.05)**
Drought (t-3)	**0.16***** **(0.04)**	**0.16***** **(0.05)**	**0.16***** **(0.04)**	**0.16***** **(0.05)**
Drought (t-4)	0.07 (0.05)	0.07 (0.05)	0.07 (0.05)	0.07 (0.05)
Bank Size			5.79*** (1.55)	5.80*** (1.72)
Bank Performance (ROE)			-0.19 (0.22)	-0.06 (0.32)
Bank Solvency (Capital Ratio)			1.28** (0.54)	1.79** (0.72)

Bank Efficiency (Op Income- Op Exp Ratio)			-3.36 (3.61)	-3.31 (4.11)
Methods	FE	Time-FE	FE	Time-FE
Observations	1,120	1,120	1,120	1,120
n	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80
t	14Q	14Q	14Q	14Q
Adj R-sq	0.5163	0.5145	0.5237	0.5216
Severe Droughts (NZPGI≤20 and consecutive days≥20)				
Drought (t)	0.10 (0.07)	0.09 (0.08)	0.09 (0.07)	0.09 (0.08)
Drought (t-1)	0.09 (0.05)	0.08 (0.06)	0.08 (0.06)	0.08 (0.06)
Drought (t-2)	**0.33*** (0.09)**	**0.31*** (0.09)**	**0.32*** (0.09)**	**0.31*** (0.09)**
Drought (t-3)	**0.26*** (0.08)**	**0.25*** (0.09)**	**0.25*** (0.08)**	**0.25*** (0.08)**
Drought (t-4)	-0.02 (0.17)	-0.01 (0.17)	-0.02 (0.16)	-0.01 (0.16)
Bank Size			5.56*** (1.55)	5.80*** (1.71)
Bank Performance (ROE)			-0.17 (0.21)	-0.06 (0.32)
Bank Solvency (Capital Ratio)			1.50*** (0.53)	1.79** (0.71)
Bank Efficiency (Op Income- Op Exp Ratio)			-3.48 (3.50)	-3.31 (4.08)
Methods	FE	Time-FE	FE	Time-FE
Observations	1,120	1,120	1,120	1,120
n	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80
t	14Q	14Q	14Q	14Q
Adj R-sq	0.5229	0.5205	0.5303	0.5276

Note: * p<0.1, ** p<0.05, *** p<0.01: robust standard errors in parentheses: Data Source: RBNZ, NIWA, and Federated Farm Surveys

After 90 days drought conditions at an additional dairy grid station in a region are associated with a bank's dairy NPLs increasing by 0.18 million NZD (for a single bank in that region). And in the following quarter the bank's dairy NPLs in the region rise by an additional 0.16 million NZD. These results hold across model specifications.

Severe drought conditions can be more harmful due to the extended dry period and increased intensity. We test our model for extreme drought and find a significantly greater impact of severe droughts on NPLs at two- and three-quarter lags. Again, the results hold across model specifications. They show an increase in banks' NPLs by 0.31 and 0.25 million NZD, respectively, two and three quarters after severe drought conditions in a region.

Overall, we may conclude that if all dairy farms in New Zealand are hit by a severe drought, then a bank's dairy NPLs can rise by 8.96 million NZD in a year, and across the New Zealand banking system NPLs would rise by an estimated 44.8 million NZD. This would be unlikely to materially affect the solvency of a large bank but could endanger the solvency of a small bank with a concentrated dairy loan portfolio.

The results show that droughts have no statistically significant impact on sheep/beef sector NPLs as shown in Table ***3.5***. Sheep/beef farms are generally less reliant on debt financing in comparison with dairy farming, and this fact may explain this result. This difference likely reflects differences in operation cycles, cost of farming, and profitability.

Table 3.5: Regression results for Droughts and NPLs of Sheep/Beef Farming

Indicators	**Total Sheep/Beef NPLs**			
	(1)	**(2)**	**(3)**	**(4)**
Droughts (NZPGI≤30 and consecutive days≥10)				
Drought (t)	0.002 (0.006)	-0.003 (0.006)	0.001 (0.006)	-0.003 (0.006)
Drought (t-1)	0.004 (0.007)	-0.002 (0.007)	0.002 (0.007)	-0.002 (0.007)
Drought (t-2)	0.003 (0.008)	-0.004 (0.010)	0.003 (0.008)	-0.004 (0.010)
Drought (t-3)	0.005 (0.009)	-0.005 (0.012)	0.002 (0.009)	-0.005 (0.012)
Drought (t-4)	0.003 (0.007)	0.002 (0.007)	0.002 (0.007)	0.002 (0.007)
Bank Size			-0.606*** (0.163)	-0.198 (0.162)
Bank Performance (ROE)			0.009 (0.055)	0.117 (0.127)
Bank Solvency (Capital Ratio)			0.104 (0.084)	-0.157 (0.126)
Bank Efficiency (Op Income- Op Exp Ratio)			-1.650 (1.209)	-1.184 (1.269)
Methods	FE	Time-FE	FE	Time-FE

Observations	1,120	1,120	1,120	1,120
n	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80
t	14Q	14Q	14Q	14Q
Adj R-sq	0.3973	0.3977	0.3990	0.3974
Severe Droughts (NZPGI≤20 and consecutive days≥20)				
Drought (t)	0.009 (0.008)	0.001 (0.007)	0.007 (0.008)	0.001 (0.007)
Drought (t-1)	0.002 (0.005)	-0.006 (0.005)	-0.002 (0.006)	-0.006 (0.005)
Drought (t-2)	0.001 (0.021)	-0.013 (0.027)	-0.009 (0.022)	-0.013 (0.027)
Drought (t-3)	0.008 (0.22)	-0.015 (0.031)	0.000 (0.220)	-0.015 (0.030)
Drought (t-4)	-0.027 (0.020)	-0.026 (0.021)	-0.027 (0.020)	-0.026 (0.021)
Bank Size			-0.599*** (0.152)	-0.198 (0.161)
Bank Performance (ROE)			-0.011 (0.057)	0.117 (0.127)
Bank Solvency (Capital Ratio)			0.076 (0.081)	-0.157 (0.126)
Bank Efficiency (Op Income- Op Exp Ratio)			-1.545 (1.222)	-1.184 (1.269)
Methods	FE	Time-FE	FE	Time-FE
Observations	1,120	1,120	1,120	1,120
n	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80
t	14Q	14Q	14Q	14Q
Adj R-sq	0.3979	0.3986	0.3997	0.3983

Note: * p<0.1, ** p<0.05, *** p<0.01: robust standard errors in parentheses: Data Source: RBNZ, NIWA, and Federated Farm Surveys

3.8 Robustness check

We also checked for the robustness of our results by using an alternative set of drought identification indicators. We used potential evapotranspiration deficit (PED) data from NIWA consolidated at the regional level for dairy farmland and sheep/beef farmland to identify the intensity of drought conditions. The PED is the difference between water that could evaporate and transpire given sufficient available water and actual evapotranspiration (Lu, Sun, McNulty, & Amatya, 2005; Mol, Tait, & Macara, 2017; Mullan, Porteous, Wratt, & Hollis, 2005). The positive PED indicates the water demand for pasture growth is not met and shows a dry period.

Therefore, we used the accumulated PED values as an indicator of drought season based on a common rule of thumb according to which an accumulation of 30 mm more PED relates to an additional week of reduced grass growth (Mol et al., 2017; Mullan et al., 2005). The regression results for both dairy and sheep/beef farming NPLs are summarized in Table ***3.7*** and Table ***3.8*** (in section 3.11 Appendix).

The results are very similar to the main findings, with the coefficients in the robustness test model having similar signs and statistical significance levels at 0.01. Thus, the main results showing a statistically significant impact of droughts on NPLs of New Zealand banks appear to be robust to how droughts are defined.

3.9 Conclusion

In this study, we analysed the frequency and intensity of droughts, both affected by climate change, as a potential determinant of agricultural NPLs in the banking sector. The previous literature includes a line of studies examining micro and macroeconomic factors as determinants of NPLs, while largely ignoring environmental factors, in spite of the discussions about climate change as a potential risk for financial institutions. Further, there is limited evidence exploring the association between climate change and the credit risk of banks. This study contributes to this emerging field of research by studying droughts as a determinant of agricultural NPLs while controlling for other micro and macroeconomic factors.

In addition, our study makes a methodological contribution by applying a spatial approach to link drought conditions to farms' locations with their banks' NPLs. Analyzing the regional occurrences of droughts and NPLs shows that droughts, identified by location, led to increased sectoral NPLs for banks, deteriorating their loan quality. All this suggests that drought risks should be incorporated into banking stress testing exercises and that lenders could potentially consider loan loss provisions against their sectoral lending in drought-prone areas.

We suggest some recommendations that can be made for farmers and the government under increased climate risk. Farmers can invest in sustainable farming practices and technologies that can reduce the impacts of climate risk. The government can provide financial support to farmers to help them adopt sustainable farming practices and technologies. The government can also provide climate risk insurance to farmers to help them manage the financial impacts of extreme weather events. The government can support research and development aimed at improving farming practices and technologies that can help reduce the impacts of climate risk on agriculture.

This research can further be extended, if additional data become available, to the connections between different types of loan portfolio exposures to various environmental risks. For example, whereas agricultural loans are vulnerable to droughts, home loans may be more vulnerable to floods. This analysis can help policymakers and banks to incorporate a wider range of portfolio-specific environmental risks in bank stress testing.

3.10 References

Battiston, S., Dafermos, Y., & Monasterolo, I. (2021). Climate risks and financial stability. *Journal of Financial Stability*, *54*, 100867. doi:https://doi.org/10.1016/j.jfs.2021.100867

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., & Visentin, G. (2017). A climate stress-test of the financial system. Nature Climate Change, 7(4), 283-288.

Berger, A. N., & DeYoung, R. (1997). Problem loans and cost efficiency in commercial banks. *Journal of Banking & Finance, 21*(6), 849-870.

Bos, J. W., Li, R., & Sanders, M. W. (2022). Hazardous lending: The impact of natural disasters on bank asset portfolio. *Economic Modelling*, 105760.

Breuer, J. B. (2006). Problem bank loans, conflicts of interest, and institutions. *Journal of financial stability, 2*(3), 266-285.

Calvet, L., Gianfrate, G., & Uppal, R. (2022). The finance of climate change. *Journal of Corporate Finance, 73,* 102162. doi:https://doi.org/10.1016/j.jcorpfin.2022.102162

Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., & Tanaka, M. (2018). Climate change challenges for central banks and financial regulators. *Nature Climate Change, 8*(6), 462-468.

Chaibi, H. (2016). Determinants of problem loans: Non-performing loans vs. loan quality deterioration. *International Business Research, 9*(10), 86-93.

Cifter, A., Yilmazer, S., & Cifter, E. (2009). Analysis of sectoral credit default cycle dependency with wavelet networks: Evidence from Turkey. *Economic Modelling, 26*(6), 1382-1388.

Copland, R., & Stevens, D. (2012). *The changing face of southern New Zealand farming: opportunities of land use change.* Paper presented at the Proceedings of the New Zealand Grassland Association.

Cortés, K. R., & Strahan, P. E. (2017). Tracing out capital flows: How financially integrated banks respond to natural disasters. *Journal of Financial Economics, 125*(1), 182-199. doi:https://doi.org/10.1016/j.jfineco.2017.04.011

Dinterman, R., Katchova, A. L., & Harris, J. M. (2018). Financial stress and farm bankruptcies in US agriculture. *Agricultural Finance Review*.

Edwards, B., Gray, M., & Hunter, B. (2009). A sunburnt country: the economic and financial impact of drought on rural and regional families in Australia in an era of climate change. *Australian Journal of Labour Economics, 12*(1), 109-131.

Escalante, C., Song, M., & Dodson, C. (2016). FSA farm loan repayment under economic recession and drought conditions. *Agricultural Finance Review*.

External Reporting Board (XRB). (2022). Climate-related Disclosures. Retrieved from https://www.xrb.govt.nz/standards/climate-related-disclosures/

Financial Markets Authority. (2022). Climate related disclosures. Retrieved from https://www.fma.govt.nz/business/focus-areas/ethical-finance/climate-related-disclosures/

Garbarino, N., & Guin, B. (2021). High water, no marks? Biased lending after extreme weather. *Journal of Financial Stability*, *54*, 100874. doi:https://doi.org/10.1016/j.jfs.2021.100874

Ghosh, A. (2015). Banking-industry specific and regional economic determinants of non-performing loans: Evidence from US states. *Journal of financial stability, 20*, 93-104. doi:https://doi.org/10.1016/j.jfs.2015.08.004

Ghosh, A. (2017). Sector-specific analysis of non-performing loans in the US banking system and their macroeconomic impact. *Journal of Economics and Business, 93*, 29-45. doi:https://doi.org/10.1016/j.jeconbus.2017.06.002

Hong, H., Li, F. W., & Xu, J. (2019). Climate risks and market efficiency. *Journal of econometrics, 208*(1), 265-281. doi:https://doi.org/10.1016/j.jeconom.2018.09.015

Institute for Economics and Peace. (2020). Drought risk score worldwide 2020, by country* Retrieved from https://www.statista.com/statistics/1099051/drought-risk-by-country/

Javadi, S., & Masum, A.-A. (2021). The impact of climate change on the cost of bank loans. *Journal of Corporate Finance, 69*, 102019. doi:https://doi.org/10.1016/j.jcorpfin.2021.102019

Konstantakis, K. N., Michaelides, P. G., & Vouldis, A. T. (2016). Non performing loans (NPLs) in a crisis economy: Long-run equilibrium analysis with a real time VEC model for Greece (2001–2015). *Physica A: Statistical Mechanics and its Applications, 451*, 149-161. doi:https://doi.org/10.1016/j.physa.2015.12.163

Lawes, R., & Kingwell, R. (2012). A longitudinal examination of business performance indicators for drought-affected farms. *Agricultural Systems, 106*(1), 94-101.

Louzis, D. P., Vouldis, A. T., & Metaxas, V. L. (2012). Macroeconomic and bank-specific determinants of non-performing loans in Greece: A comparative study of mortgage, business and consumer loan portfolios. *Journal of Banking & Finance, 36*(4), 1012-1027.

Lu, J., Sun, G., McNulty, S. G., & Amatya, D. M. (2005). A Comparison of Six Potential Evapotranspiration Methods for Regional Use in the Southeastern United States 1. *JAWRA Journal of the American Water Resources Association, 41*(3), 621-633.

Manz, F. (2019). Determinants of non-performing loans: What do we know? A systematic review and avenues for future research. *Management Review Quarterly, 69*(4), 351-389.

Mol, A., Tait, A., & Macara, G. (2017). An automated drought monitoring system for New Zealand. *Weather and Climate, 37*(1), 23-36.

Mullan, B., Porteous, A., Wratt, D., & Hollis, M. (2005). Changes in drought risk with climate change. *Prepared for Ministry for the Environment (NZ Climate Change Office) and Ministry of Agriculture and Forestry. NIWA Client Report: WLG2005–23.(National Institute of Water and Atmospheric Research, Wellington)*.

Nagarajan, R. (2009). Drought indices. In *Drought assessment* (pp. 160-204): Springer Science & Business Media.

National Institute of Water & Atmospheric Research Ltd. (2020). Drought hits hard, far and wide. Retrieved from https://niwa.co.nz/news/drought-hits-hard-far-and-wide

National Institute of Water & Atmospheric Research Ltd. (2021). NZ Drought indicator products and information. Retrieved from https://niwa.co.nz/climate/information-and-resources/drought-monitor/drought-indicator

Nguyen, Q., Diaz-Rainey, I., Kuruppuarachchi, D., McCarten, M., & Tan, E. K. (2023). Climate transition risk in US loan portfolios: Are all banks the same? *International Review of Financial Analysis, 85*, 102401.

Podpiera, J., & Weill, L. (2008). Bad luck or bad management? Emerging banking market experience. *Journal of financial stability, 4*(2), 135-148.

Pourzand, F., Noy, I., & Sağlam, Y. (2020). Droughts and farms' financial performance: a farm-level study in New Zealand. *Australian Journal of Agricultural and Resource Economics, 64*(3), 818-844. doi:10.1111/1467-8489.12367

Radivojević, N., Cvijanović, D., Sekulic, D., Pavlovic, D., Jovic, S., & Maksimović, G. (2019). Econometric model of non-performing loans determinants. *Physica A: Statistical Mechanics and its Applications, 520*, 481-488. doi:https://doi.org/10.1016/j.physa.2019.01.015

Reserve Bank of New Zealand. (2020). Overview of the New Zealand Financial System - The Banking System. Retrieved from https://www.rbnz.govt.nz/financial-stability/overview-of-the-new-zealand-financial-system/the-banking-system

Reserve Bank of New Zealand. (2021a). Banks: Assets – Loans by purpose (S31). Retrieved from https://www.rbnz.govt.nz/statistics/s31-banks-assets-loans-by-purpose

Reserve Bank of New Zealand. (2021b). Capital adequacy. Retrieved from https://bankdashboard.rbnz.govt.nz/capital-adequacy

Reserve Bank of New Zealand. (2021c). *Financial Stability Report May 2021*. Retrieved from https://www.rbnz.govt.nz/financial-stability/financial-stability-report

Reserve Bank of New Zealand. (2022). How we approach climate-related risk. Retrieved from https://www.rbnz.govt.nz/about-us/how-we-work/how-we-approach-climate-related-risk

Rinaldi, L., & Sanchis-Arellano, A. (2006). Household debt sustainability: What explains household non-performing loans? An empirical analysis. *ECB Working Paper, No. 570*. doi:http://dx.doi.org/10.2139/ssrn.872528

Salas, V., & Saurina, J. (2002). Credit risk in two institutional regimes: Spanish commercial and savings banks. *Journal of Financial Services Research, 22*(3), 203-224.

Tran, L. T., Stoeckl, N., Esparon, M., & Jarvis, D. (2016). If climate change means more intense and more frequent drought, what will that mean for agricultural production? A case study in Northern Australia. *Australasian Journal of Environmental Management, 23*(3), 281-297.

Vazquez, F., Tabak, B. M., & Souto, M. (2012). A macro stress test model of credit risk for the Brazilian banking sector. *Journal of financial stability, 8*(2), 69-83.

Yevjevich, V. M. (1967). Objective approach to definitions and investigations of continental hydrologic droughts, An. *Hydrology papers (Colorado State University); no. 23*.

3.11 Appendix

Table 3.6: The Financial performance of dairy and sheep/beef farms

Variable	Dairy Farms			Sheep/Beef Farms		
	2018	**2019**	**2020**	**2018**	**2019**	**2020**
Income (NZD in m)	13,537	13,773	14,810	9,775	10,038	10,267
Expenditure (NZD in m)	11,658	12,204	12,520	8,286	8,686	8,741
Profit (NZD in m)	1,746	1,523	2,287	1,630	1,476	1,241
Assets (NZD in m)	64,724	65,924	68,503	48,441	50,766	51,934
Business count	14,298	14,634	14,673	22,401	22,494	22,563
Employee count	25,300	25,200	24,700	19,350	19,600	18,400

Source: StatsNZ Business Performance Benchmarker

Table 3.7: Regression results for Droughts and NPLs of Dairy Farming using PED

Indicators	Total Dairy NPLs			
	(1)	**(2)**	**(3)**	**(4)**
Droughts (Accumulated PED > 150mm)				
Drought (t)	0.02 (0.02)	0.01 (0.02)	0.02 (0.02)	0.01 (0.02)
Drought (t-1)	0.01 (0.01)	0.01 (0.02)	0.01 (0.01)	0.01 (0.02)
Drought (t-2)	**0.05***** **(0.02)**	**0.05***** **(0.02)**	**0.05***** **(0.01)**	**0.05***** **(0.02)**
Bank Size			4.85** (2.13)	5.79** (1.68)
Bank Performance (ROE)			-0.42 (0.32)	-0.06 (0.43)
Bank Solvency (Capital Ratio)			1.81** (0.80)	1.79* (1.03)
Bank Efficiency (Op Income- Op Exp Ratio)			-4.73 (4.76)	-3.31 (5.25)
Methods	FE	Time-FE	FE	Time-FE
Observations	1,120	1,120	1,120	1,120
n	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80
t	14Q	14Q	14Q	14Q
Adj R-sq	0.487	0.4931	0.4993	0.5001
Severe Droughts (Accumulated PED > 180mm)				
Drought (t)	0.03 (0.02)	0.02 (0.03)	0.03 (0.02)	0.02 (0.03)

Drought (t-1)	0.02 (0.02)	0.01 (0.03)	0.01 (0.02)	0.01 (0.03)
Drought (t-2)	**0.07***** **(0.02)**	**0.07***** **(0.02)**	**0.07***** **(0.02)**	**0.07***** **(0.02)**
Bank Size			4.83** (2.11)	5.73** (2.18)
Bank Performance (ROE)			-0.43 (0.31)	-0.06 (0.43)
Bank Solvency (Capital Ratio)			1.77** (0.79)	1.80* (1.03)
Bank Efficiency (Op Income- Op Exp Ratio)			-4.64 (4.64)	-3.38 (5.27)
Methods	FE	Time-FE	FE	Time-FE
Observations	1,120	1,120	1,120	1,120
n	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80
t	14Q	14Q	14Q	14Q
Adj R-sq	0.4873	0.4933	0.4997	0.5002

Note: * p<0.1, ** p<0.05, *** p<0.01: robust standard errors in parentheses: Data Source: RBNZ, NIWA, and Federated Farm Surveys

Table 3.8: Regression results for Droughts and NPLs of Sheep/Beef Farming using PED

Indicators	**Total Sheep and Beef NPLs**			
	(1)	**(2)**	**(3)**	**(4)**
Droughts (Accumulated PED > 150mm)				
Drought (t)	0.000 (0.002)	-0.001 (0.002)	0.000 (0.002)	-0.001 (0.002)
Drought (t-1)	0.001 (0.002)	0.000 (0.002)	0.000 (0.002)	0.000 (0.002)
Drought (t-2)	-0.002 (0.002)	-0.005 (0.002)	-0.003* (0.001)	-0.005* (0.002)
Bank Size			-0.629*** (0.223)	-0.198 (0.228)
Bank Performance (ROE)			0.018 (0.071)	0.117 (0.154)
Bank Solvency (Capital Ratio)			0.113 (0.087)	-0.157 (0.160)
Bank Efficiency (Op Income- Op Exp Ratio)			-1.899 (1.697)	-1.184 (1.585)
Methods	FE	Time-FE	FE	Time-FE
Observations	1,120	1,120	1,120	1,120
n	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80

t	14Q	14Q	14Q	14Q
Adj R-sq	0.3993	0.4018	0.402	0.4015
Severe Droughts (Accumulated PED > 180mm)				
Drought (t)	-0.002 (0.004)	-0.004 (0.004)	-0.002 (0.003)	-0.004 (0.004)
Drought (t-1)	-0.001 (0.004)	-0.003 (0.005)	-0.001 (0.004)	-0.003 (0.005)
Drought (t-2)	-0.004 (0.003)	-0.008* (0.004)	-0.004 (0.003)	-0.008* (0.004)
Bank Size			-0.637*** (0.230)	-0.198 (0.235)
Bank Performance (ROE)			0.010 (0.070)	0.117 (0.153)
Bank Solvency (Capital Ratio)			0.102 (0.084)	-0.157 (0.162)
Bank Efficiency (Op Income- Op Exp Ratio)			-1.809 (1.649)	-1.184 (1.582)
Methods	FE	Time-FE	FE	Time-FE
Observations	1,120	1,120	1,120	1,120
n	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80	5 x 16 = 80
t	14Q	14Q	14Q	14Q
Adj R-sq	0.3995	0.4026	0.4021	0.4024

Note: * p<0.1, ** p<0.05, *** p<0.01: robust standard errors in parentheses: Data Source: RBNZ, NIWA, and Federated Farm Surveys

Table 3.9: Top 10 dairy and sheep/beef commodities export countries and their respective drought risk for the year 2020

Rank	**Country**	**Commodity**	**Netweight (kg millions)**	**Export Countries Count**	**Trade Value* (US$ millions)**	**World Market share**	**Drought Risk****
1	Brazil	Meat of bovine animals	1,558.5		6,679.1	25%	2.8
2	Australia	Meat of bovine animals	804.3		3,972.9	15%	3.64
3	US	Meat of bovine animals	513.7		2,991.6	11%	2.8
4	India	Meat of bovine animals	934.3		2,762.4	10%	3.44
5	New Zealand	Meat of bovine animals	436.1		2,100.7	8%	1.6
6	Argentina	Meat of bovine animals	527.9		2,058.6	8%	2.24
7	Uruguay	Meat of bovine animals	271.1		1,264.9	5%	1.72
8	Paraguay	Meat of bovine animals	157.1		591.3	2%	2.44
9	Canada	Meat of bovine animals	82.0		400.9	2%	2.92
10	Ireland	Meat of bovine animals	105.6		400.4	2%	1.2
Total export value of a commodity by all countries counts				**88**	**26,325.1**		
1	Australia	Meat of sheep or goats	446.8		2,636.9	37%	3.64
2	New Zealand	Meat of sheep or goats	401.5		2,532.4	35%	1.6

3	United Kingdom	Meat of sheep or goats	88.2		564.5	8%	1.2
4	Ireland	Meat of sheep or goats	56.7		390.3	5%	1.2
5	Spain	Meat of sheep or goats	43.2		223.6	3%	2.8
6	Netherlands	Meat of sheep or goats	24.1		197.7	3%	1.2
7	Uruguay	Meat of sheep or goats	14.9		75.6	1%	1.72
8	France	Meat of sheep or goats	9.0		64.2	1%	1.92
9	Belgium	Meat of sheep or goats	6.7		62.5	1%	1.2
10	Kenya	Meat of sheep or goats	12.5		55.8	1%	3.8
Total export value of a commodity by all countries counts				**80**	**7,159.0**		
1	New Zealand	Milk and cream	1,891.1		5,848.5	29%	1.6
2	US	Milk and cream	868.3		2,168.5	11%	2.8
3	Germany	Milk and cream	730.7		1,578.3	8%	1.2
4	Netherlands	Milk and cream	608.1		1,563.9	8%	1.2
5	France	Milk and cream	450.8		1,100.2	5%	1.92
6	Belgium	Milk and cream	355.1		883.6	4%	1.2
7	Australia	Milk and cream	215.6		671.2	3%	3.64
8	Ireland	Milk and cream	236.0		641.9	3%	1.2
9	China, HK SAR	Milk and cream	29.3		498.3	2%	2.84
10	Argentina	Milk and cream	167.2		492.4	2%	2.24
Total export value of a commodity by all countries counts				**105**	**20,009.1**		
1	New Zealand	Butter and dairy spreads	425.3		1,891.7	22%	1.6
2	Netherlands	Butter and dairy spreads	319.7		1,361.1	16%	1.2
3	Ireland	Butter and dairy spreads	301.4		1,159.2	14%	1.2
4	Germany	Butter and dairy spreads	155.5		669.6	8%	1.2
5	Belgium	Butter and dairy spreads	-		668.6	8%	1.2
6	France	Butter and dairy spreads	91.7		529.1	6%	1.92
7	Belarus	Butter and dairy spreads	-		387.7	5%	2.24
8	Denmark	Butter and dairy spreads	50.5		268.9	3%	1.92
9	United Kingdom	Butter and dairy spreads	61.4		241.6	3%	1.2
10	Poland	Butter and dairy spreads	57.2		223.4	3%	1.6
Total export of a commodity by all countries counts				**97**	**8,554.1**		
1	Germany	Cheese and curd	1,312.8		4,800.4	15%	1.2
2	Netherlands	Cheese and curd	920.9		4,217.0	13%	1.2
3	Italy	Cheese and curd	463.5		3,561.7	11%	2.12
4	France	Cheese and curd	656.5		3,504.0	11%	1.92
5	US	Cheese and curd	358.5		1,611.6	5%	2.8
6	Denmark	Cheese and curd	399.0		1,604.6	5%	1.92
7	New Zealand	Cheese and curd	327.0		1,316.5	4%	1.6
8	Ireland	Cheese and curd	281.8		1,177.4	4%	1.2
9	Belarus	Cheese and curd	-		1,064.4	3%	2.24
10	Belgium	Cheese and curd	233.9		971.5	3%	1.2
Total export value of a commodity by all countries counts				**100**	**32,614.0**		

* Data extracted from UN Comtrade Database for the year 2020 https://comtrade.un.org/data

** Drought risk score worldwide 2020, by country measures where droughts are likely to occur, the population and assets exposed, and the vulnerability of the population and assets to suffering adverse effects. Higher values indicate a higher risk of drought. Scores are on a scale from 0 to 5. The higher the score, the greater the exposure to water stress (IEP, 2020).

Table 3.10: Computation of land coverage for dairy farming and sheep/beef farming in New Zealand

Regions	**Land Area* in Sq Km (A)**	**Dairy Land** in Sq Km (B)**	**%age Dairy Land Occupant B/A x 100 [C]**	**Sheep and Beef Land** in Sq Km (D)**	**%age Sheep and Beef Land Occupant D/A x 100 [E]**
Auckland	4,938	740	**15**	1,471	**30**
Bay of Plenty	12,071	1,739	**14**	1,893	**16**
Canterbury	44,508	6,731	**15**	24,180	**54**
Gisborne	8,386	370	**4**	4,648	**55**
Hawke's Bay	14,137	1,039	**7**	7,633	**54**
Manawatū-Whanganui	22,220	3,559	**16**	12,000	**54**
Marlborough	10,458	445	**4**	4,208	**40**
Nelson	424	13	**3**	55	**13**
Northland	12,499	3,039	**24**	4,785	**38**
Otago	31,209	3,217	**10**	20,848	**67**
Southland	31,195	4,446	**14**	9,114	**29**
Taranaki	7,254	2,934	**40**	2,584	**36**
Tasman	9,616	604	**6**	1,154	**12**
Waikato	23,902	8,814	**37**	8,309	**35**
Wellington	8,049	984	**12**	3,883	**48**
West Coast	23,244	1,224	**5**	972	**4**
Others	2,976		**-**		**-**
Total	**267,086**	**39,898**	**15**	**107,737**	**40**

Note:

* The regional land area is obtained from Stats NZ Regional Council 2013 GIS data. https://datafinder.stats.govt.nz/layer/25738-regional-council-2013/data/

** The figures presented are based on the agricultural production surveys which include all units identified on Statistics New Zealand's Business Frame as having agricultural activity. The Business Frame is a list of businesses in New Zealand, based on their registration for goods and services tax (GST) with Inland Revenue. It should be noted that the compulsory registration level for GST is $60,000, so there is partial and unquantifiable coverage of units below this level. This measure includes the total area of farms that have one or more total dairy cattle.

Source: Statistics New Zealand

Chapter 4: **Exploring the differential impact of droughts on dairy, sheep, and beef export: A multi-country panel study from 1995-2020**

Abstract

We investigate the impact of droughts on dairy, sheep, and beef sector exports – measured in terms of both volume and value. The study produces estimates at the world, and income level, based on data from UN Comtrade, the World Bank, and a measure of droughts (the Standardized Precipitation Evapotranspiration Index) of regularly exporting countries from 1995-2020. Findings suggest that droughts, over the period considered, have a significant impact on agricultural export quantities of dairy, sheep, and beef. We found a larger reduction in dairy export quantities during droughts for medium-low-income countries whereas high-income countries show a higher reduction in beef and sheep export quantities, during and after droughts. We also found that the impact of droughts on export values is positive for the dairy sector while it is negative for the sheep sector.

4.1 Introduction

Droughts are expected to increase in frequency and severity of occurrence worldwide by the end of the 21st century due to the progression of climate change (Pachauri & Meyer, 2014). That exposes economies and societies to risk. The risk arises from the interaction between hazards such as droughts, vulnerability, and exposure. In recent years (2001-2017), about 20% of global lands were affected by drought and in some of these years, the impact was more than 20% (Kogan, 2019). Losses from droughts, especially in agriculture, are staggering. For example, in the USA, drought ranks third among costly weather disasters since 1980, behind tropical cyclones and severe storms. The cost of drought events in the USA averages over $9 billion per year and jumped to $60 billion in extreme drought years such as 1988 (NIDIS, 2022). In Europe, weather and climate-related extremes accounted for around 80% of total economic losses amounting to EUR 487 billion caused by natural hazards, an average of EUR 11.9 billion per year, between 1980 and 2020 (EEA, 2022). Whereas the drought damages in the European Union and the United Kingdom could strongly increase from €9 billion per year to more than €65 billion per year with a 4 °C global warming in 2100 under no climate action (Naumann, Cammalleri, Mentaschi, & Feyen, 2021). Droughts in the Mediterranean regions have severe impacts on the agriculture sector, and increasing drought risk in various regions in Europe is expected to reduce livestock productivity through negative impacts on grassland productivity and animal health (EEA, 2019). In Australia, the estimated economic losses from the 2017-2019 drought were $53 billion (Wittwer & Waschik, 2021). Similarly, Low-income countries of Africa and Asia have been the most drought-affected by food shortages, population displacement, and mortality. (Kogan, 2019). In Africa from 1970 to 2019 droughts caused US$ 10.01 billion in economic damages (WMO, 2021). The agricultural losses to droughts could increase to up to 7% of GDP by 2100 in northern, western central and southern Africa (IPCC, 2007).

While droughts have the potential to affect an entire economy, the agricultural sector is particularly vulnerable. Previous studies suggest that droughts have a significant impact on agricultural production patterns, and in particular, yields and farm income (e.g., Godfrey et al., 2021; Kingwell & Xayavong, 2017; Kuwayama, Thompson, Bernknopf, Zaitchik, & Vail, 2019; Pourzand, Noy, & Sağlam, 2020). Droughts affect the production and trade in agricultural markets. A key concern is that the frequency and intensity of future droughts will be higher than past droughts (Mullan, Porteous, Wratt, & Hollis, 2005). This can lead to a greater decrease in agricultural production reducing net farm income by a higher margin and, also affecting countries that are dependent on agriculture trade.

While prior studies have explored the impact of disasters on international trade (Osberghaus, 2019), we believe a deeper inquiry is warranted to explore the impact of droughts on agricultural exports. Specifically, Osberghaus (2019) in their review of 21 studies on the effects of natural disasters and weather variation on international trade note that most studies measure trade in monetary terms largely ignoring the issue of price effects. Further, very few studies have explored weather effects on the international trade of agricultural products (Barua & Valenzuela, 2018; Dallmann, 2019; Jones & Olken, 2010; Li, Xiang, & Gu, 2015).

Droughts can impact the supply of agricultural goods, which can lead to changes in the quantity and value of exports. For example, if droughts reduce the quantity of dairy products available for export, this is because the input cost has increased as the farmers may need to buy feed for animals. Therefore, making it less profitable for farmers to produce and sell the dairy products at the same price. This shift in the supply curve can result in a new equilibrium point at a higher price and lower quantity, reflecting the increased cost of production. When there is a decrease in supply, it can lead to a shortage of the product in the market. This can cause a few different reactions from consumers. First, some consumers may be willing to pay a higher price to obtain the product, also leading to an increase in the equilibrium price. This increase in price will result in a decrease in the quantity of exports, as the higher price will make the goods less affordable to foreign buyers. The interaction between supply and demand can be used to understand the impacts of droughts on exports, both in terms of the quantity of goods exported and the value of those exports.

Therefore, we extend prior research and ask*: What is the impact of drought on dairy, beef and sheep sector exports measured in terms of volume and value?*

This study, utilizing data from UN Comtrade, the World Bank, and a drought index (the global SPEI database), investigates the impact of drought on export volume and value using detailed estimates of the SPEI as a drought measure for countries involved in dairy, sheep, and beef exports, from 1995 to 2020. Unlike other studies, we investigate exports in terms of quantity and value at the country level and account for the price effect. We argue that the impact of drought on agricultural exports can be through the following ways: (i) on export quantity due to change in agricultural production and (ii) on export values earned due to change in prices and quantity. The reduction in agriculture production may affect the trade quantity and trade value differently due to changes in prices.

The remainder of the chapter is organized as follows: Section 4.2 provides a background of the literature on climate-related events and international trade. Sections 4.3, 4.4, 4.5, and 4.6 describe drought identification around the world, data, world exports – dairy, sheep, and beef, and the estimated model, respectively. We provide results and discussion in section 4.7, and robustness check in section 4.8. The last section concludes.

4.2 Literature background

Considering the greater sensitivity of agricultural activities to droughts, the international trade of agricultural goods could be affected by droughts the most as compared to manufacturing goods (Barua & Valenzuela, 2018). Recent research has examined the impacts of droughts on agriculture production and farm income. Interestingly, in a few studies, the impact on farm income is found to be positive. For example, 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. Pourzand et al. (2020) found that drought events have positive impacts on dairy farms' revenue and profit in the year of a drought in New Zealand. While some studies show a negative impact of droughts. Such as, Kuwayama et al. (2019) found negative and statistically significant effects for each additional week of drought in dryland counties in the U.S. on corn and soybean yields but negligible to no effect on measures of farm income. Furthermore, Naumann et al. (2021) recently estimated that droughts account for more than half of total agricultural losses in Europe and 60% in the Mediterranean region. Godfrey et al. (2021) discovered lower profitability for farms in South-Eastern Australia with higher debt accumulation due to drought shocks. These findings lead us to consider if the farm income changes due to the shifting of farms' sales of production from local market to international market via exports. Despite a drop in agricultural production due to droughts, a farmer may receive a higher price in global trade, resulting in a positive income. Therefore, we investigate another strand of studies finding impact on international trade.

Several studies have examined the impacts of climate shocks on international trade. For example, Jones and Olken (2010) used historical weather data on temperature and precipitation, as well as US and UN trade data on exports to the US and exports to all countries, to assess the impact of climate shocks on exports.of 22 products. They discovered that average temperature increases in a given year have a large negative impact on poor-country exports but no impact on rich-country exports, whereas precipitation change has no impact on US imports but has a positive impact on exports. They also found that temperature increases have a significant negative impact on the exports of cereals and preparations, dairy and eggs. Li et al. (2015) using product-city level data aggregated exports and imports data at one Standard International Trade Classification (SITC) digit level suggested that temperature has a significant negative impact on both Chinese exports and imports, while precipitation has a moderate positive impact on export.

More recently, Barua and Valenzuela (2018) evaluate the temperature and precipitation variations on total and six sectoral agricultural exports at a global, regional, and economic level, using export data for 102 countries for the period from 1962 to 2014. They found that climate variations have significant impacts on agriculture exports globally and that grains, oil seeds, livestock, and dairy and eggs, are significantly vulnerable to increases in the level of temperature. Moreover, they also found that low-income countries are substantially more affected by the effects of increasing temperature than high-income countries. Dallmann (2019) using panel data for 134 countries over the 1992–2014 period investigate the impact of weather variations in exporting and importing countries, on bilateral trade flows and found a negative effect of temperature variations[17] on bilateral trade. Further, a report by the Food and Agriculture Organization of the United Nations (FAO) shows a limited availability of dairy exports from Australia and New Zealand due to dry weather conditions in Australia and New Zealand between January and May 2019 (FAO, 2020).

In summary, the relationship between droughts and agricultural trade is ubiquitous. As the studies take into account the trade measured in monetary terms. The reason may be to account for the unit of measurement being unique across a group of products or consolidated amounts of trade across countries. Given the evidence of the vulnerability of agricultural yield to droughts, we expect the impacts of drought on agriculture-based trade value could be different from agriculture-based trade quantity due to changes in prices, their market share and competitiveness in world trade. Therefore, this study contributes to evaluating drought

[17] A change in average temperature from one period to another period.

variations on dairy, sheep/ beef sectoral agricultural exports at a global level in terms of quantity, and value.

4.3 Drought identification around the world:

To quantify the intensity, duration, magnitude and spatial extent of droughts, different quantitative indices were developed for analysis and monitoring of droughts. The key parameters used in evaluating drought situations by different indices are rainfall, temperature, evaporation, and soil moisture (Nagarajan, 2009). The focus of monitoring of these indices is either agricultural droughts, hydrological or meteorological droughts[18]. There are four distinctive methods of measuring and estimating drought: meteorological (temperature and precipitation), land cover (vegetation), soil moisture, and remote sensing (normalized difference vegetation index (NDVI)) (Kogan, 2019). Some of these indices include the Palmer Drought Severity Index (PDSI) (Palmer, 1965), the Standardised Precipitation Index (SPI) (McKee, Doesken, & Kleist, 1993), and the standardized precipitation evapotranspiration index (SPEI) (Sergio M Vicente-Serrano, Beguería, & López-Moreno, 2010). These indices have their strengths and weaknesses.

Most studies used PDSI, or SPI to analyse droughts and monitoring systems. PDSI is based on precipitation and temperature, and is effective in determining long-term droughts, but is not

[18] Meteorological drought is defined as a lack of precipitation over a region for a period, and hydrological drought is related to a period with inadequate surface and subsurface water resources for established water uses of a given water resources management system. While Agricultural drought refers to a period with declining soil moisture and consequent crop failure without any reference to surface water resources (Mishra & Singh, 2010).

comparable across regions[19] and lacks multi-timescale features[20] (Dai & NCARS, 2019). While SPI uses precipitation only, more comparable across regions uses multi-timescale but does not account for evapotranspiration (Keyantash & NCARS, 2018). To address the shortcomings of both PDSI and SPI, SPEI was formulated based on precipitation and potential evapotranspiration (PET). The SPEI combines the sensitivity of PDSI to changes in evaporation demand (caused by temperature fluctuations and trends) with the multi-timescale nature of the SPI. The SPEI can account for the possible effects of temperature variability and temperature extremes thus more appropriate to study the effect of global warming on drought severity (Vicente-Serrano & NCARS, 2015). Therefore, SPEI is preferable for the identification, analysis and monitoring of droughts in any climate region of the world (Peña-Gallardo et al., 2019; Sergio M Vicente-Serrano et al., 2010). Further, Keyantash and Dracup (2002) established the evaluation criteria for drought indices based on desirable properties that an index should ideally possess, that drought indices must be statistically robust and easily calculated, and have a clear and comprehensible calculation procedure. All these requirements are met by the SPEI. The SPEI allows comparison of drought severity through time and space since it can be calculated over a wide range of climates (Vicente-Serrano & NCARS, 2015). Therefore, we used SPEI to identify the drought conditions at the country level.

The values of SPEI correspond to a standard normal variable comparable in time and space and are classified into seven categories as shown in Table ***4.10*** (in section 4.11.2 Appendix – Tables). We identify the drought conditions as “1” if the SPEI value is less than or equal to -1,

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[19] Palmer used the standardization based on limited data from the central US and index was more sensitive in the Great Plains than other regions in US to yield severe PDSI (Dai & NCARS, 2019)

[20] Palmer used the data aggregated on the annual level and adjusted for monthly values, therefore not comparable between months (Alley, 1984).

else “0”. Then we computed the percentage of drought-affected areas for each country every year. We further applied an arbitrary threshold to identify if drought conditions hit the agricultural land of that country in a year or not. If the country holds more than 40% agricultural land and the percentage of drought coverage is more than 60%, then the drought variable is assigned the value “1” or else “0”. That arbitrary threshold is set to assume at least an agriculture area is affected by drought identified through SPEI. We expect changes in our arbitrary threshold will change our results too like increasing the country's agricultural land area meaning applying a wider impact of drought on the country’s agricultural land may also increase our estimate results. More detail on SPEI data and construction of drought variable using SPEI is provided in following sections ***4.4*** (Data) and ***4.6*** (Model) respectively.

Figure ***4.1*** shows the countries impacted by drought conditions during the time 1995-2020. Our analysis shows Africa, Europe, Asia, Oceania and North America are the most drought-prone regions in the world. El Salvador, Moldova, Macedonia, Morocco and Uganda are the most affected countries[21] by drought. El Salvador is facing successive years of drought since 2012 (Dunem, 2022). The least drought-affected countries are China, Chile, Canada, Brazil, Bolivia and Austria.

[21] From the list of our sample countries as shown in Table ***4.9*** (in section 4.11.2 Appendix – Tables)

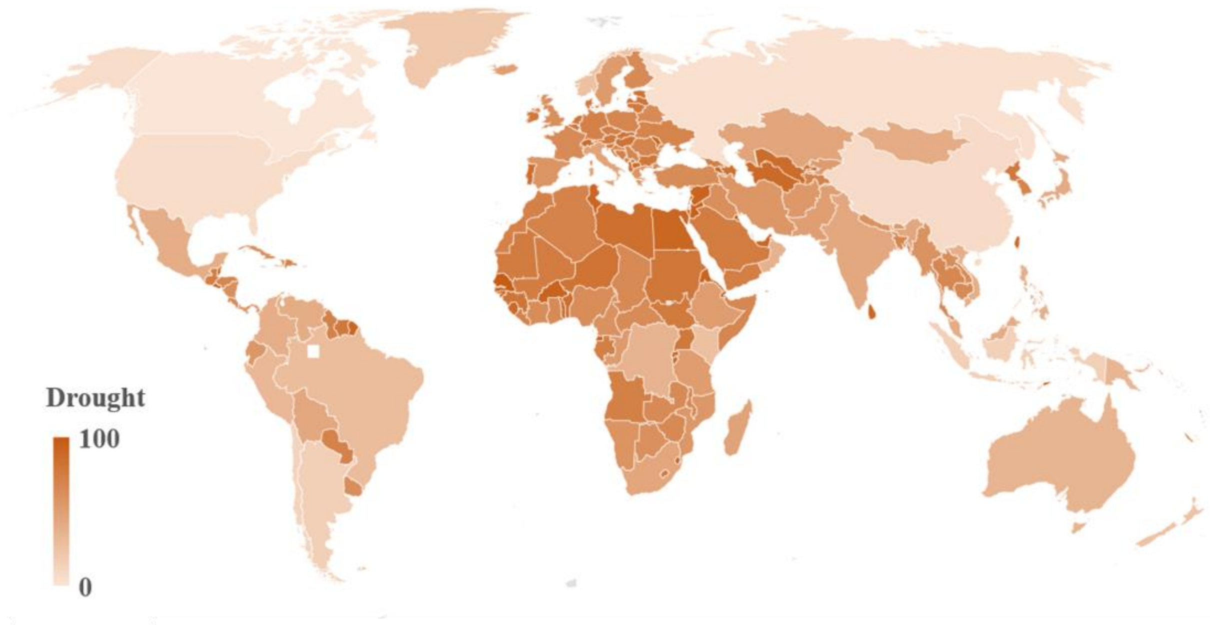

Figure 4.1: The map shows countries affected by drought in percentage between 1995-2020 based on SPEI < -1

4.4 Data

The historical global SPEI database is taken under the open database license, SPEIbase (*Global SPEI database*, 2022). This dataset provides long-time (from January 1901 to December 2020), information about drought conditions at the global scale, with a 0.5 degrees spatial resolution (grid points approximately 56km x 56km at the equator) and a monthly time resolution. From global scale data, we identified and separated the grid points at the country-month level. We identify the drought conditions at each grid point based on the SPEI scale of values at the country-month level. Then we computed the percentage of drought-affected grid points out of the total grid points of a country each month. This percentage data shows drought coverage at the country-month level. Further, to identify the data at the year level, we selected the maximum percentage value of a month in a year, as we know the drought season may vary from country to country. Therefore, choosing the highest value from monthly data helps us to capture and compare the widespread drought conditions at the country-year level.

In addition, we used agricultural land (percentage of land area)[22] data acquired from The World Bank data bank (WB, 2022a). That is used to further precise our drought identification approach of applying an additional threshold at agricultural land of a country year level, as defined in section ***4.3***. That helps us to match our dependent variable focusing on the agriculture sector only at the country-year level with the drought variable measured at the same agricultural land of country-year level.

The trade data for dairy, sheep and beef come from United Nations Trade Data available on the official website of UN Comtrade (UN, 2022). We aggregate dairy data to two of the HS 4-digit[23] codes focused on milk and cream categories only, as our analysis includes the impact of droughts on trade quantities as well, so we only grouped the quantities having an identical unit of measurement. Similarly, the sheep and beef trade data are aggregated to one or two of the HS 4-digit codes focused on specific categories only. The description of selected HS codes and their sectoral classification as dairy, sheep and beef is provided in Table ***4.8*** (in section 4.11.2 Appendix – Tables).

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[22] Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures. Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded. Land under permanent crops is land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee, and rubber. This category includes land under flowering shrubs, fruit trees, nut trees, and vines, but excludes land under trees grown for wood or timber. Permanent pasture is land used for five or more years for forage, including natural and cultivated crops (WB, 2022a).

[23] The Harmonized System (HS) is a standardized numerical method of classifying traded products. It is used by customs authorities around the world to identify products when assessing duties and taxes and for gathering statistics.

We have data from 60 countries for 26 years from 1995 to 2020. We restrict our attention to those countries only where we observe regular exports of dairy, sheep, and beef in years (1995-2020). Collectively, they hold a market share of more than 90% (See Table ***4.9*** in section 4.11.2 Appendix – Tables). Further, countries are divided into high-income groups and middle- and low-income group countries based on the world bank[24] classification of economies based on gross national income per capita. The classification of countries is shown in Table ***4.9*** (in section 4.11.2 Appendix – Tables). The list of variables[25] is defined in Table ***4.1*** below:

Table 4.1: List of variables and definitions

Variables	Definitions	Data Source
Dairy export quantity (kg in mil)	The sum of quantity weighted in kilograms exported from a country to the world of specific dairy products grouped under HS codes 401 and 402 descriptions (milk and cream)	UN Comtrade
Dairy export value (USD in mil)	The total of the value measured in USD, exported from a country to the world of specific dairy products grouped under HS codes 0401 and 0402 descriptions (milk and cream)	UN Comtrade
Sheep export quantity (kg in mil)	The sum of quantity weighted in kilograms exported from a country to the world of specific sheep products grouped under HS code 0204 description (meat of sheep or goats)	UN Comtrade
Sheep export value (USD in mil)	The total value measured in USD, exported from a country to the world of specific sheep products grouped under HS code 0204 description (meat of sheep or goats)	UN Comtrade
Beef export quantity (kg in mil)	The sum of quantity weighted in kilograms exported from a country to the world of specific beef products grouped under HS codes 0201 and 0202 descriptions (meat of bovine animals)	UN Comtrade

[24] Economies are currently divided into four income groupings: low, lower-middle, upper-middle, and high, based on gross national income (GNI) per capita (in U.S. dollars, converted from local currency estimated by World Bank. (WB, 2022b).

[25] Our response variables are log transformed for better interpretation of results and symmetrical distribution of data

Beef export value (USD in mil)	The total of the value measured in USD, exported from a country to the world of specific beef products grouped under HS codes 0201 and 0202 descriptions (meat of bovine animals)	UN Comtrade
Drought – Dairy	Drought conditions identified in dairy exporting countries (from our sample countries only)	SPEI database
Drought – Sheep	Drought conditions identified in sheep exporting countries (from our sample countries only)	SPEI database
Drought – Beef	Drought conditions identified in beef exporting countries (from our sample countries only)	SPEI database

4.5 World exports – Dairy, Sheep and Beef

More than 9% of the total dairy produced around the world is traded internationally[26]. Similarly, about 17% of beef meat is traded in its total production globally[27]. Figure ***4.2***, shows the total export value of dairy, sheep, and beef over the years 1995-2020. We can observe rapid growth in export values from the year 2003. Over the last 20 years, regional trade agreements, reduction in tariff protections, and WTO accession resulted in a boost in agricultural goods trade. In the year 2001, China joins WTO is another contributing factor to raising export values (WTO, 2015). In 2015, the dollar value of world merchandise trade fell sharply by 13 per cent, largely as a result of lower commodity prices and a general appreciation of the US dollar (WTO, 2016).

[26] The dairy production around the world was nearly 928 million tonnes and International dairy trade nearly 88 million tonnes in 2021 (FAO, 2022a).
[27] The beef production around the world was nearly 72.5 million tonnes and International dairy trade nearly 12.1 million tonnes in 2021 (FAO, 2022b)

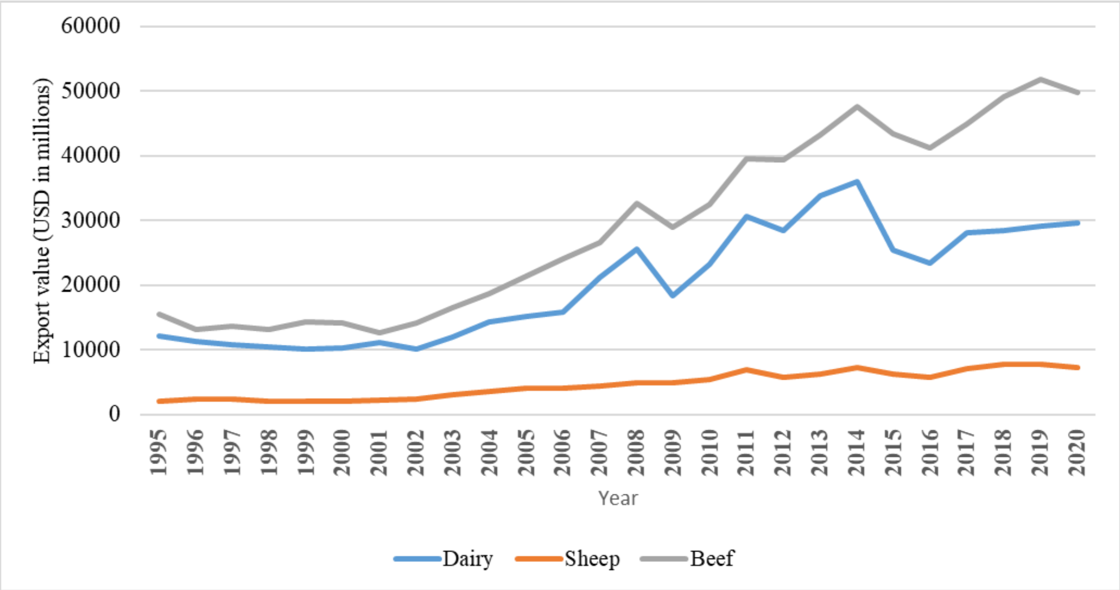
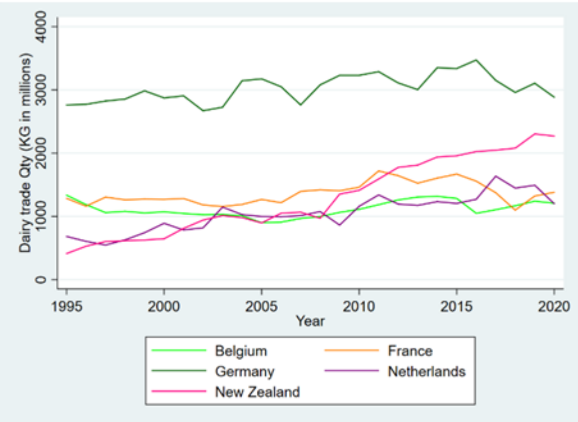


Figure 4.2: The total export value of dairy, sheep, and beef to the world from the years 1995-2020

We further look into the leading countries of export to the world in terms of quantity and value of dairy, sheep, and beef respectively.



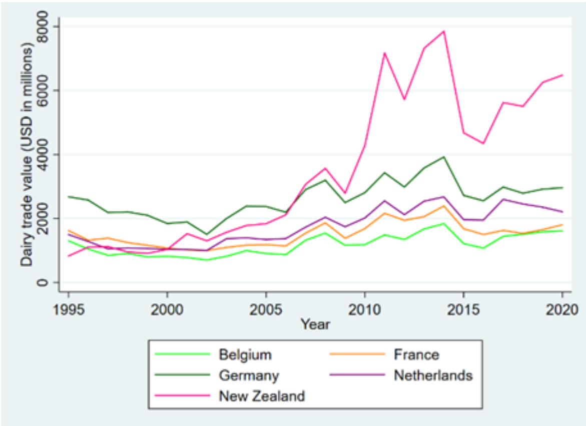


Figure 4.3: Top dairy exporting countries over the years 1995-2020 showing results in terms of quantity and value (from left to right)

Figure ***4.3*** shows the top dairy exporters in the world in terms of quantity export and the value generated. We can observe from the figure that Germany is the leading dairy quantity exporter in the world, while New Zealand leads in terms of value generated from dairy export. The previous studies suggest that the law of one price does not hold, and that location and currency-adjusted milk and dairy products price levels change largely across exporting countries (Newton, 2016).

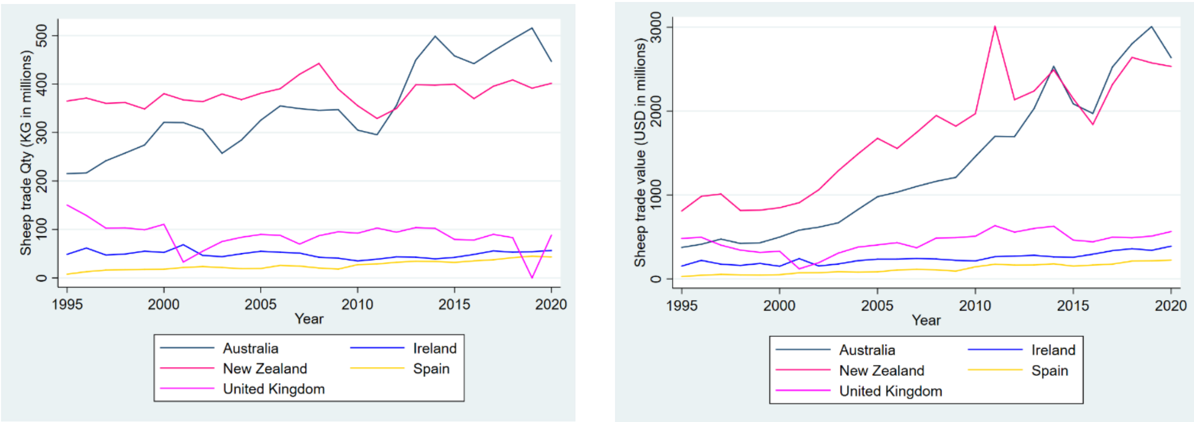
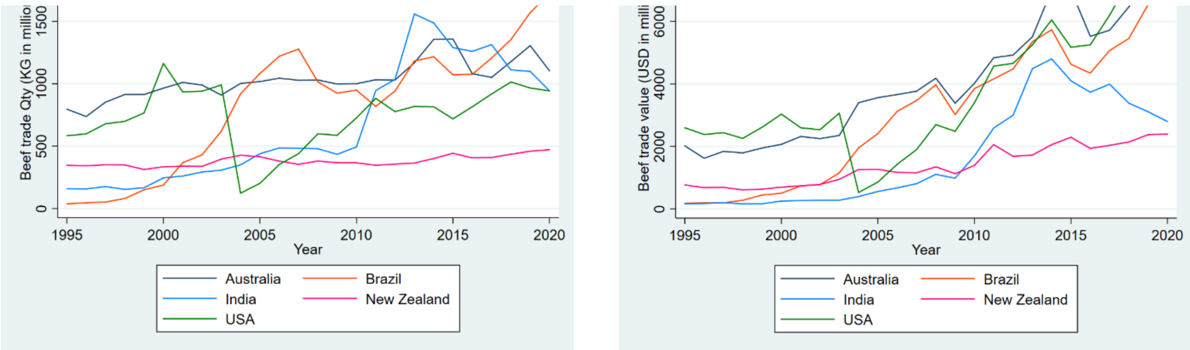


Figure 4.4: Top sheep exporting countries over the years 1995-2020 showing results in terms of quantity and value (from left to right)



Australia and New Zealand are top sheep exporters to the world in terms of both quantity and value as shown in Figure ***4.4***. The average market share in the sheep trade of each country is shown in Table ***4.9*** (in section 4.11.2 Appendix – Tables). The United Kingdom, Ireland and Spain are following leading exporters of sheep to the world. About 93% of the market in sheep exports is held by high-income countries while a very small contribution by medium-low-income countries.

The top beef exporter to the world varies over the years 1995-2020 as shown in Figure ***4.5***. On average USA and Australia are the beef export leaders in the world as shown in Table ***4.9*** (in section 4.11.2 Appendix – Tables). In the year 2004, the USA beef exports fell by 83% due to mad cow disease (Jeremy & Koo, 2007). Brazil has shown an increasing trend in beef exports and currently holds around 23% market share in beef exports.

Figure ***4.6*** to Figure ***4.8*** (in section 4.11.1 Appendix – Figures) show composite graphs of total exports in terms of quantity, value, and no. of countries over the years 1995-2020 for dairy, sheep and beef respectively.

4.6 Model

The estimating equation follows Jones and Olken (2010). To estimate the relationship between drought shocks and international trade of dairy, sheep and beef, we estimate the following

Figure 4.5: Top beef exporting countries over the years 1995-2020 showing results in terms of quantity and value (from left to right)

equations, regressing the exports of dairy, sheep and beef on drought conditions in the exporting country:

$$LogY_{it} = \beta_1 D_{it} + \varepsilon_i + \mu_t + u_{it} \qquad (1)$$

$$LogY_{it} = \beta_1 D_{it} + \beta_2 D_{i,t-1} + \varepsilon_i + \mu_t + u_{it} \qquad (2)$$

In these specifications of (1) and (2), Y_{it} is the export quantity measured in kilograms or export value measured in USD of dairy, sheep, and beef, of country *i* in time *t*. D_{it} is the binary variable indicating drought conditions computed through SPEI for country i at time t, using the thresholds described above. The country fixed effects, ε_i, capture fixed differences in the exports of dairy, sheep, and beef from country i. The year fixed effects, μ_t, capture time-specific worldwide shocks in the trade of dairy, sheep, and beef such as changes in prices and worldwide recessions. u_{it} is an iid error term representing unobserved factors that change over time and affect Y_{it}. In equation (2) we added a year lag of droughts i.e. $D_{i,t-1}$ to see the after-drought impacts. We assume the homogeneous prices across countries for the harmonisation of our test. We estimate equations (1) and (2) by FGLS to adjust the large range of variances among series. We corrected the heteroskedastic error structure and the residuals of panels that are correlated (Greene, 2003). We tested for cross-sectional dependence using the Pasaran CD test and found the residuals are correlated across countries. Similarly, we used the Wald test for countrywide heteroskedasticity and found the presence of heteroskedasticity as shown in Table ***4.2*** below. These results lead us to use FGLS as an estimation method because we have macro panels with long time series of over 20 years.

Table 4.2: Tests results for cross-sectional dependence using Pesaran CD test and heteroskedasticity using Wald test

Results of Pesaran Cross-sectional Dependence (CD) test			
H_0: No Cross-Sectional Dependence			
	Dairy	Sheep	Beef
Pesaran Test	16.407	5.52	13.898
P-value	0	0	0
Avg. the absolute value of the off-diagonal elements	0.374	0.269	0.346
Results	Reject H_0	Reject H_0	Reject H_0
Results of Wald test for GroupWise heteroskedasticity by Modified Wald test			
H_0: sigma(i)^2 = sigma^2 for all i (i.e., Variance of the error term is constant, homoskedasticity)			
	Dairy	Sheep	Beef
Wald test	chi^2 (57) = 1.4^{e+05}	chi^2 (33) = 79261.05	chi^2 (49) = 1.4^{e+05}
P-value	Prob>chi^2 = 0.0000	Prob>chi^2 = 0.0000	Prob>chi^2 = 0.0000
Results	Reject H_0	Reject H_0	Reject H_0

4.7 Results and discussion

Table ***4.3*** describes the sample size for our dataset of dairy, sheep, and beef sectors across all, medium-low-income and high-income countries. Our sample identifies 57 regular dairy export countries from the period 1995-2020, of which 21 and 36 are classified as high-income and medium-low-income countries respectively. From the beef sector, we identified 15 medium-low-income, 34 high-income and 49 in total from the list of regular exporting countries under the same period of study. Whereas 33 in all, 8 in medium-low-income and 25 in high-income countries list of regular sheep exporters from the period of 1995-2020.

Table 4.3: Sample size

Indicators	**All Countries**		**Medium-low-income Countries**		**High-income Countries**	
	No. of countries	**No. of observations**	**No. of countries**	**No. of observations**	**No. of countries**	**No. of observations**
Dairy	57	1,482	21	546	36	936
Beef	49	1,274	15	390	34	884
Sheep	33	858	8	208	25	650
Time (t) in years	26	26	26	26	26	26

Table ***4.4*** presents the basic statistics of our sample. On average the high-income countries supply most of the dairy exports and as a result, earn more than medium-low-income countries. Ultimately, on average they hold a greater market share and contribute more to their country's GDP. The beef export quantity is equally distributed between high-income and medium-low-income countries on average. However, in terms of the value of beef exports, the medium-low-income countries lead the high-income countries on average generating approximately 1,300 million USD. The higher standard deviation around the values indicates the low concentrated market for beef and dairy exports while the highly concentrated market for sheep exports is shown in Figure ***4.9*** to Figure ***4.11*** (in section 4.11.1 Appendix – Figures).

Table 4.4: Descriptive Statistics

Indicators	**All Countries**		**Medium-low-income Countries**		**High-income Countries**	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Dairy Qty (kg/mil)	239.11	508.25	28.67	43.13	361.86	605.92
Dairy Val (USD/mil)	340.40	1,005.97	180.53	1,188.43	433.67	869.52
Beef Qty (kg/mil)	141.04	259.85	134.74	307.89	143.81	235.70
Beef Val (USD/mil)	801.26	4,637.48	1,342.33	8,203.62	562.01	1,060.24
Sheep Qty (kg/mil)	30.36	88.75	4.16	7.28	38.74	100.47
Sheep Val (USD/mil)	123.06	390.75	23.45	40.62	155.03	443.88
Drought - Dairy	0.40	0.49	0.38	0.49	0.41	0.49
Drought - Beef	0.40	0.49	0.40	0.49	0.40	0.49
Drought - Sheep	0.46	0.50	0.56	0.50	0.43	0.50

4.7.1 DAIRY – EXPORT QUANTITIES AND EXPORT VALUES

Table 4.5 shows the regression results of the impact of drought on export quantities and export values of dairy for all countries, medium-low-income and high-income countries. In model 1 we tested the impact during drought conditions by employing current time (t) only. While in model 2 we added a year lag to see the impact of drought. The coefficients of the drought (t) and drought (t-1) are negative and statistically significant at 1% for dairy export quantities for all, medium-low-income and high-income countries. Drought seems to reduce the dairy export quantities by 25% significantly and the long-term impact is 36%[28]. The impact of drought on medium-low-income countries is much higher than in high-income countries.

The regression results for the same specifications but with export values as a dependent variable are shown under the same table. For dairy export values the results are very different from dairy export quantities. The coefficient of the current year drought (t) is positive and statistically significant at 1% for all countries. Once we include drought (t-1), the coefficient value dropped from 9% to 6% but was still statistically significant at 5%. The export values of dairy are positively associated with drought measures, opposite to what we observed for dairy export quantities.

The estimated results for income group classification the coefficients of the current year drought (t) and drought (t-1) are positive and statistically significant at 1% for high-income countries. Whereas the coefficient of the drought (t-1) is negative and statistically significant at 1% for medium-low-income countries.

[28] To interpret the results in percentage we exponentiate the coefficient, subtract one from this number, and multiply by 100.

Table 4.5: Drought effects on export quantities and export values of the dairy sector from all, medium-low-income and high-income countries

Indicators	All Countries		Medium-low-income Countries		High-income Countries	
	Log Qty (kg)					
Model	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Drought (t)	-0.29*** (0.03)	-0.25*** (0.05)	-0.63*** (0.04)	-0.74*** (0.03)	-0.16*** (0.01)	-0.14*** (0.01)
Drought (t-1)		-0.15*** (0.05)		-0.37*** (0.03)		-0.18*** (0.01)
Obs	1,482	1,425	546	525	936	900
n	57	57	21	21	36	36
t (years)	26	25	26	25	26	25
	Log Val (USD)					
Drought (t)	0.09*** (0.02)	0.06** (0.03)	-0.03 (0.03)	-0.05* (0.03)	0.06*** (0.01)	0.06*** (0.01)
Drought (t-1)		0.04* (0.03)		-0.23*** (0.03)		0.03*** (0.01)
Obs	1,482	1,425	546	525	936	900
n	57	57	21	21	36	36
t (years)	26	25	26	25	26	25

Notes: Each specification includes country and year fixed effects. Standard errors in parentheses.
** p<0.1, ** p<0.05, *** p<0.01*

4.7.2 SHEEP – EXPORT QUANTITIES AND EXPORT VALUES

Table ***4.6*** provides the regression results for the same specifications as in

Table 4.5, but of sheep for all countries, medium-low-income and high-income countries. For sheep export quantities the results are quite like dairy export quantities. The coefficient of the current year drought (t) is negative and statistically significant at 1% for all countries. Once we include drought (t-1), the coefficient value remains consistent and statistically significant at 1%. The export values of sheep are negatively associated with drought measures, opposite to what we observed for the dairy export values in

Table 4.5.

The estimated results of sheep export quantities for income group classification the coefficients of the current year drought (t) and drought (t-1) are negative and statistically significant at 1%

for high-income countries. Similarly sheep export values coefficient of the current year drought (t) is negative and statistically significant at 1% for high-income countries. It shows drought reduces sheep export quantities by 26% to 44 % and export values by 10% in high-income countries. The percentage of reduction in quantities is higher than values indicating an increase in prices. Whereas no significant impact was observed on sheep export quantities and values for medium-low-income countries. This may be due to the sheep export share in the world market being heavily held by the high-income countries, as shown in Table ***4.9*** (in section 4.11.2 Appendix – Tables).

Table 4.6: Drought effects on export quantities and export values of sheep sector from all, medium-low-income and high-income countries

Indicators	**All Countries**		**Medium-low-income Countries**		**High-income Countries**	
	Log Qty (kg)					
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Drought (t)	-0.21*** (0.01)	-0.20*** (0.01)	0.28 (0.21)	0.05 (0.17)	-0.29*** (0.01)	-0.30*** (0.01)
Drought (t-1)		-0.08*** (0.01)		0.28* (0.17)		-0.20*** (0.01)
Obs	858	825	208	200	650	625
n	33	33	8	8	25	25
t (years)	26	25	26	25	26	25
	Log Val (USD)					
Drought (t)	-0.09*** (0.01)	-0.09*** (0.01)	0.10 (0.16)	0.28 (0.18)	-0.12*** (0.01)	-0.11*** (0.01)
Drought (t-1)		0.05*** (0.01)		0.18 (0.18)		-0.01 (0.01)
Obs	858	825	208	200	650	625
n	33	33	8	8	25	25
t (years)	26	25	26	25	26	25

Notes: Each specification includes country and year fixed effects. Standard errors in parentheses.
** p<0.1, ** p<0.05, *** p<0.01*

4.7.3 BEEF – EXPORT QUANTITIES AND EXPORT VALUES

Table ***4.7*** provides the estimation of the impact of droughts on beef exports to the world. Similar to dairy and sheep results, the coefficients of the drought (t) and drought (t-1) are negative and statistically significant at 1% for beef export quantities for all countries. However, no significant impact was observed for medium-low-income countries' beef export quantities. For the high-low-income countries, there is a significant (at a 1% level of significance) reduction in beef export quantities. It shows drought reduces beef export quantities by 31% to 55% in high-income countries. Similar estimation results were found for sheep export quantities.

For beef export values no significant results were observed for all countries but as we segregate between medium-low-income and high-income countries, we observed the opposite results for both groups of countries. The coefficient of the current year drought (t) and drought (t-1) is positive and statistically significant at 1% for medium-low-income countries. It shows droughts have a positive impact on increasing beef export values for medium-low-income countries by 39% to 75%. Whereas, for the high-income countries there is a significant (at a 1% level of significance) reduction in their beef export values by 17% to 28% during and after drought season.

These findings indicate that droughts have a negative impact on beef export quantities in the global market. The beef export quantities reduction is of higher margin for high-income countries and their export values are reduced as well. However, there was no significant impact of droughts on beef export quantities observed for medium-low-income countries, but their beef export values increased. We may say they take the advantage of reduced beef supply in the world market.

Table 4.7: Drought effects on export quantities and export values of the beef sector from all, medium-low-income and high-income countries

Indicators	**All Countries**		**Medium-low-income Countries**		**High-income Countries**	
	Log Qty (kg)					
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Drought (t)	-0.23*** (0.03)	-0.24*** (0.03)	0.07 (0.06)	0.06 (0.07)	-0.36*** (0.01)	-0.37*** (0.01)

Drought (t-1)		-0.21*** (0.03)		-0.02 (0.06)		-0.27*** (0.01)
Obs	1,274	1,225	390	375	884	850
n	49	49	15	15	34	34
t (years)	26	25	26	25	26	25
	Log Val (USD)					
Drought (t)	0.02 (0.02)	-0.01 (0.02)	0.33*** (0.04)	0.35*** (0.05)	-0.19*** (0.01)	-0.19*** (0.01)
Drought (t-1)		0.02 (0.02)		0.29*** (0.05)		-0.12*** (0.01)
Obs	1,274	1,225	390	375	884	850
n	49	49	15	15	34	34
t (years)	26	25	26	25	26	25

Notes: Each specification includes country and year fixed effects. Standard errors in parentheses.
** p<0.1, ** p<0.05, *** p<0.01*

4.8 Robustness Check

We also estimated a set of regressions using alternative drought indicators threshold to test whether our results are robust. Since we applied an arbitrary threshold to identify if drought conditions hit the agricultural land of that country in a year or not. If the country holds more than 40% agricultural land and the percentage of drought coverage is more than 60%, then the drought variable is assigned the value “1” or else “0”. That arbitrary threshold is set to assume at least an agriculture area is affected by drought identified through SPEI. We expect changes in our arbitrary threshold will change our results too like increasing the country’s agricultural land area meaning applying a wider impact of drought on the country’s agricultural land may also increase our estimate results. Therefore, we tested for, if the country holds more than 50% agricultural land and the percentage of drought coverage is more than 60%, then the drought variable is assigned the value “1” or else “0”. The regression results of export quantities and export values worldwide, and income level samples for dairy, sheep and beef industries are summarised in Table ***4.12*** to Table ***4.14*** (in section 4.11.2 Appendix – Tables).

Our results are stronger in terms of increasing coefficient values to the prior findings, with the similar sign of coefficients or in their statistical significance. Our results appear robust and there is much evidence for significant impacts of drought conditions on export quantities and export values of dairy, sheep, and beef industries worldwide over the time we investigated, once arbitrary thresholds changed.

In addition, in Figure ***4.5*** we observe, that the USA beef exports fell by 83% due to mad cow disease in the year 2004 (Jeremy & Koo, 2007) and we also observed a reduction in beef export quantities by 31% to 55% for high-income countries. To test if our results are influenced by USA beef export drop, we tested our model by dropping the USA from our sample list. The results are shown in Table ***4.11*** (in section 4.11.2 Appendix – Tables), we didn't observe any changes in the initial results as reported in Table ***4.7***.

4.9 Conclusion

Our findings suggested that droughts, over the period considered, have a significant impact on agricultural exports (dairy, sheep, and beef). Droughts significantly reduce dairy export quantities from low-income countries, while they increase dairy export values for high-income countries. These results suggest a reduction in dairy quantity supplied to the world market during or after drought episodes and benefits for the dairy exporting countries in earning dairy export values.

Exports of sheep and beef from high-income countries are found significantly vulnerable to droughts in terms of reducing export quantities, and values. The high-income countries hold the major share in the beef and sheep world market and their quantity supplied in the world market is reduced by a great margin, but their export values are not reduced by the same percentage as reduced in export quantities. Whereas the exports of beef from medium-low-income countries are found significantly beneficial to droughts in terms of increasing export values. The medium-low-income countries hold a minor share in the beef world market and their quantity supplied shows no significant impact of droughts but takes advantage of increased export values.

Further, we observed from our results the percentage of reduction in export quantities is higher than the export values, which indicates there may be a role of prices as a result of reduced quantity supply in the world market during and after drought episodes. Future research may explore the impact of drought on price determination. In addition, the opposite results of export values for dairy, sheep and beef farming suggest there may be a different selling strategy adopted by these sectors. We again leave this for further exploration.

The findings provide detailed evidence of how agricultural export of dairy sheep and beef patterns are vulnerable or beneficial to drought conditions, and they could be used in further projections considering droughts as a determinant of agricultural production and trade.

4.10 References

Alley, W. M. (1984). The Palmer drought severity index: limitations and assumptions. *Journal of Applied Meteorology and Climatology*, *23*(7), 1100-1109. doi:https://doi.org/10.1175/1520-0450(1984)023<1100:TPDSIL>2.0.CO;2

Barua, S., & Valenzuela, E. (2018). *Climate change impacts on global agricultural trade patterns: evidence from the past 50 years.* Paper presented at the Proceedings of the Sixth International Conference on Sustainable Development.

Dai, A., & National Center for Atmospheric Research Staff (Eds). (2019). The Climate Data Guide: Palmer Drought Severity Index (PDSI). *The Climate Data Guide: Palmer Drought Severity Index (PDSI).* Retrieved from https://climatedataguide.ucar.edu/climate-data/palmer-drought-severity-index-pdsi

Dallmann, I. (2019). Weather variations and international trade. *Environmental and resource economics*, *72*(1), 155-206.

Dunem, A. V. (2022). Nature-Based Solutions Reduce Climate Impact in El Salvador. Retrieved from https://www.visionofhumanity.org/can-nature-based-solutions-offer-climate-resilience-in-el-salvador/

European Environment Agency. (2019). *Climate change adaptation in the agriculture sector in Europe1994-2019*. Retrieved from https://www.eea.europa.eu/publications/cc-adaptation-agriculture

European Environment Agency. (2022). Economic losses from climate-related extremes in Europe. Retrieved from https://www.eea.europa.eu/ims/economic-losses-from-climate-related

Food and Agriculture Organization of the United Nations. (2020). *Overview of global dairy market developments in 2019*. Retrieved from Rome, Italy: https://www.fao.org/publications/card/en/c/ca8341en/

Food and Agriculture Organization of the United Nations. (2022a). *Dairy Market Review: Overview of global dairy market and policy developments in 2021*. Retrieved from Rome: https://www.fao.org/markets-and-trade/commodities/dairy/en/

Food and Agriculture Organization of the United Nations. (2022b). *Meat Market Review 2021*. Retrieved from Rome: https://www.fao.org/markets-and-trade/commodities/meat/en/

Global SPEI database. (2022). Retrieved from: https://spei.csic.es/database.html

Godfrey, S. S., Nordblom, T., Ip, R. H., Robertson, S., Hutchings, T., & Behrendt, K. (2021). Drought shocks and gearing impacts on the profitability of sheep farming. *Agriculture*, *11*(4), 366.

Greene, W. H. (2003). *Econometric analysis*: Pearson Education India.

Intergovernmental Panel on Climate Change (IPCC). (2007). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental*

Panel on Climate Change. Retrieved from United Kingdom and New York, NY, USA.: https://www.ipcc.ch/report/ar4/wg3/

Jeremy, W. M., & Koo, W. W. (2007). Effects of Bovine Spongiform Encephalopathy Outbreaks on U.S. Cattle and Beef Prices. *Review of Agricultural Economics, 29*(4), 734-748.

Jones, B. F., & Olken, B. A. (2010). Climate shocks and exports. *American Economic Review*, *100*(2), 454-459.

Keyantash, J., & Dracup, J. A. (2002). The quantification of drought: an evaluation of drought indices. *Bulletin of the American Meteorological Society*, *83*(8), 1167-1180.

Keyantash, J., & National Center for Atmospheric Research Staff (Eds). (2018). The Climate Data Guide: Standardized Precipitation Index (SPI). *The Climate Data Guide: Standardized Precipitation Index (SPI).* Retrieved from https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi

Kingwell, R. S., & Xayavong, V. (2017). How drought affects the financial characteristics of Australian farm businesses. *Australian Journal of Agricultural and Resource Economics, 61*(3), 344-366.

Kogan, F. (2019). Monitoring drought from space and food security. In *Remote sensing for food security* (pp. 75-113): Springer.

Kuwayama, Y., Thompson, A., Bernknopf, R., Zaitchik, B., & Vail, P. (2019). Estimating the impact of drought on agriculture using the US Drought Monitor. *American Journal of Agricultural Economics, 101*(1), 193-210.

Li, C., Xiang, X., & Gu, H. (2015). Climate shocks and international trade: Evidence from China. *Economics Letters, 135*, 55-57.

McKee, T. B., Doesken, N. J., & Kleist, J. (1993). *The relationship of drought frequency and duration to time scales.* Paper presented at the Proceedings of the 8th Conference on Applied Climatology.

Mishra, A. K., & Singh, V. P. (2010). A review of drought concepts. *Journal of hydrology, 391*(1-2), 202-216.

Mullan, B., Porteous, A., Wratt, D., & Hollis, M. (2005). Changes in drought risk with climate change. *Prepared for Ministry for the Environment (NZ Climate Change Office) and Ministry of Agriculture and Forestry. NIWA Client Report: WLG2005–23.(National Institute of Water and Atmospheric Research, Wellington).*

Nagarajan, R. (2009). Drought indices. In *Drought assessment* (pp. 160-204): Springer Science & Business Media.

National Integrated Drought Information System. (2022). Drought Impacts on Agriculture. Retrieved from https://www.drought.gov/sectors/agriculture

Naumann, G., Cammalleri, C., Mentaschi, L., & Feyen, L. (2021). Increased economic drought impacts in Europe with anthropogenic warming. *Nature Climate Change*, 1-7.

Newton, J. (2016). Price transmission in global dairy markets. *International Food and Agribusiness Management Review, 19*(1030-2016-83107), 57-71.

Osberghaus, D. (2019). The effects of natural disasters and weather variations on international trade and financial flows: a review of the empirical literature. *Economics of Disasters and Climate Change, 3*(3), 305-325.

Pachauri, R., & Meyer, L. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Palmer, W. C. (1965). *Meteorological drought* (Vol. 30): US Department of Commerce, Weather Bureau.

Peña-Gallardo, M., Vicente-Serrano, S. M., Quiring, S., Svoboda, M., Hannaford, J., Tomas-Burguera, M., . . . El Kenawy, A. (2019). Response of crop yield to different time-scales of drought in the United States: Spatio-temporal patterns and climatic and environmental drivers. *Agricultural and Forest Meteorology, 264*, 40-55.

Pourzand, F., Noy, I., & Sağlam, Y. (2020). Droughts and farms' financial performance: a farm-level study in New Zealand. *Australian Journal of Agricultural and Resource Economics, 64*(3), 818-844. doi:10.1111/1467-8489.12367

The World Bank. (2022a). Data Bank. Retrieved from https://databank.worldbank.org/metadataglossary/world-development-indicators/series/AG.LND.AGRI.ZS

The World Bank. (2022b). How does the World Bank classify countries? Retrieved from https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries
United Nations. (2022). UN Comtrade Database. Retrieved from https://comtrade.un.org/data/
Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A multiscalar drought index sensitive to global warming: the standardized precipitation evapotranspiration index. *Journal of climate, 23*(7), 1696-1718.
Vicente-Serrano, S. M., & National Center for Atmospheric Research Staff (Eds). (2015). The Climate Data Guide: Standardized Precipitation Evapotranspiration Index (SPEI). *The Climate Data Guide: Standardized Precipitation Evapotranspiration Index (SPEI)*. Retrieved from https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-evapotranspiration-index-spei
Wittwer, G., & Waschik, R. (2021). Estimating the economic impacts of the 2017–2019 drought and 2019–2020 bushfires on regional NSW and the rest of Australia. *Australian Journal of Agricultural and Resource Economics, 65*(4), 918-936.
World Meteorological Organization (WMO). (2021). *WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019)*. Retrieved from https://library.wmo.int/index.php?lvl=notice_display&id=21930#.Ywg1xnZByUm
World Trade Organization. (2015). *International Trade Statistics 2015*. Retrieved from https://www.wto.org/english/res_e/statis_e/its2015_e/its15_toc_e.htm
World Trade Organization. (2016). *REPORT TO THE TPRB FROM THE DIRECTOR-GENERAL ON TRADE-RELATED DEVELOPMENTS*. Retrieved from https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/WT/TPR/OVW10.pdf

4.11 Appendix

4.11.1 Appendix - Figures

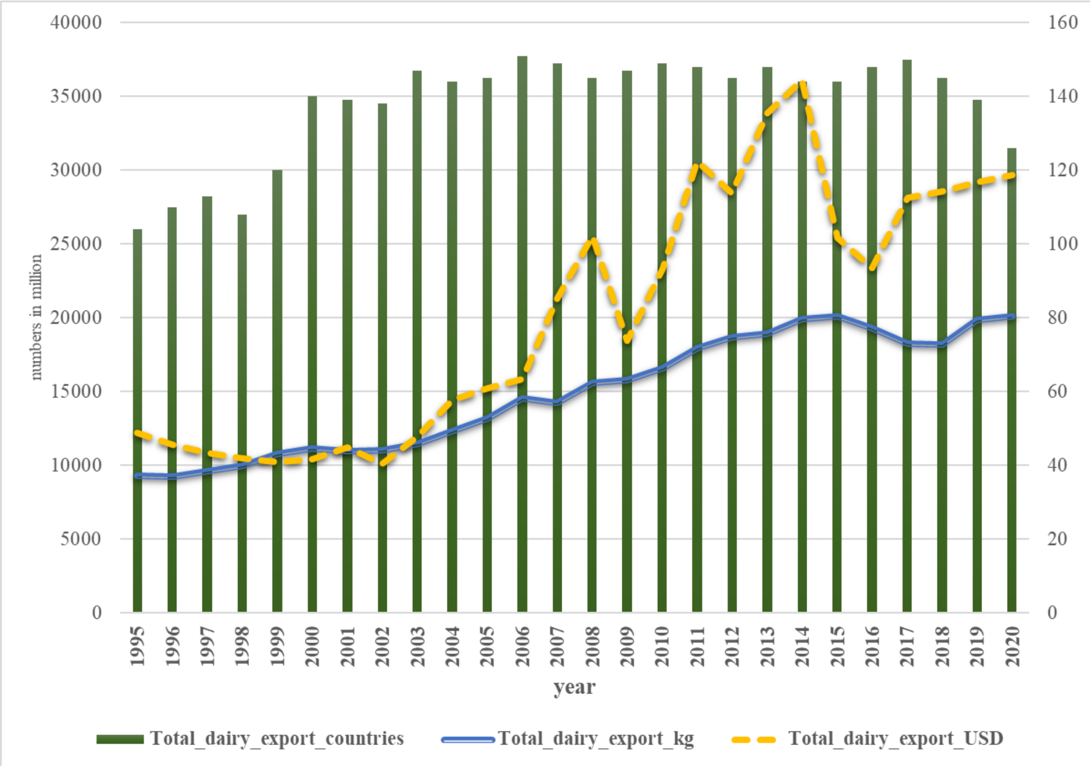


Figure 4.6: Total dairy export to the world in terms of quantity, value, and no. of countries over the years 1995-2020

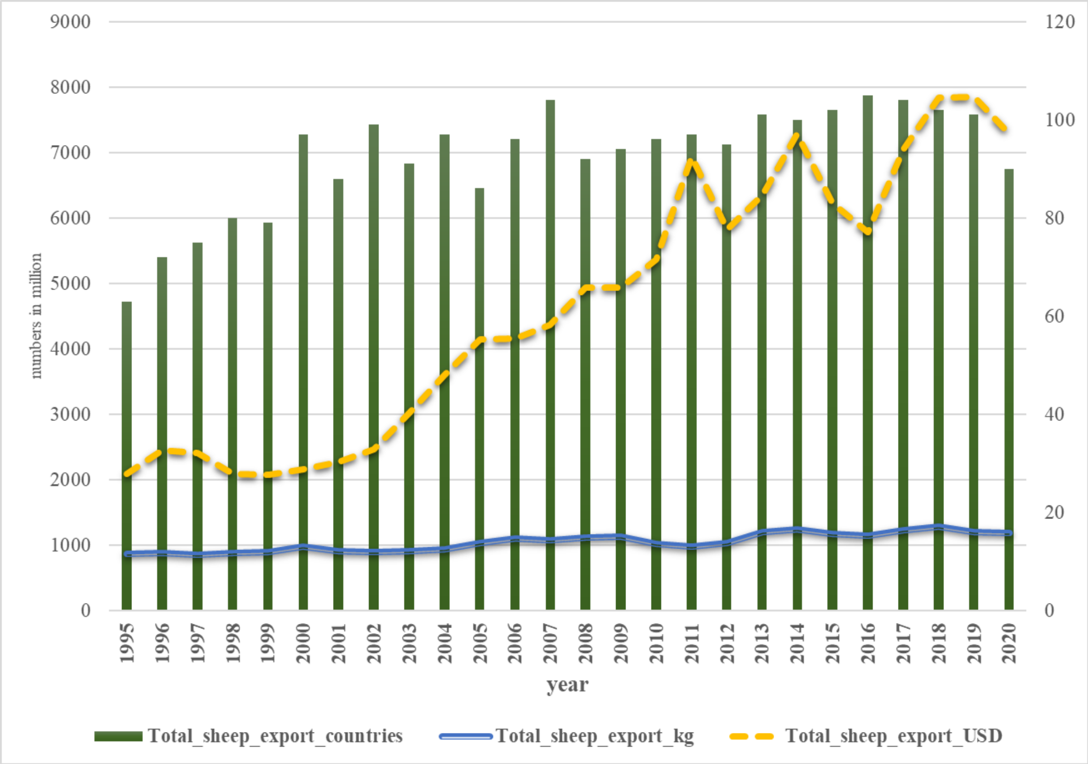


Figure 4.7: Total sheep export to the world in terms of quantity, value, and no. of countries over the years 1995-2020

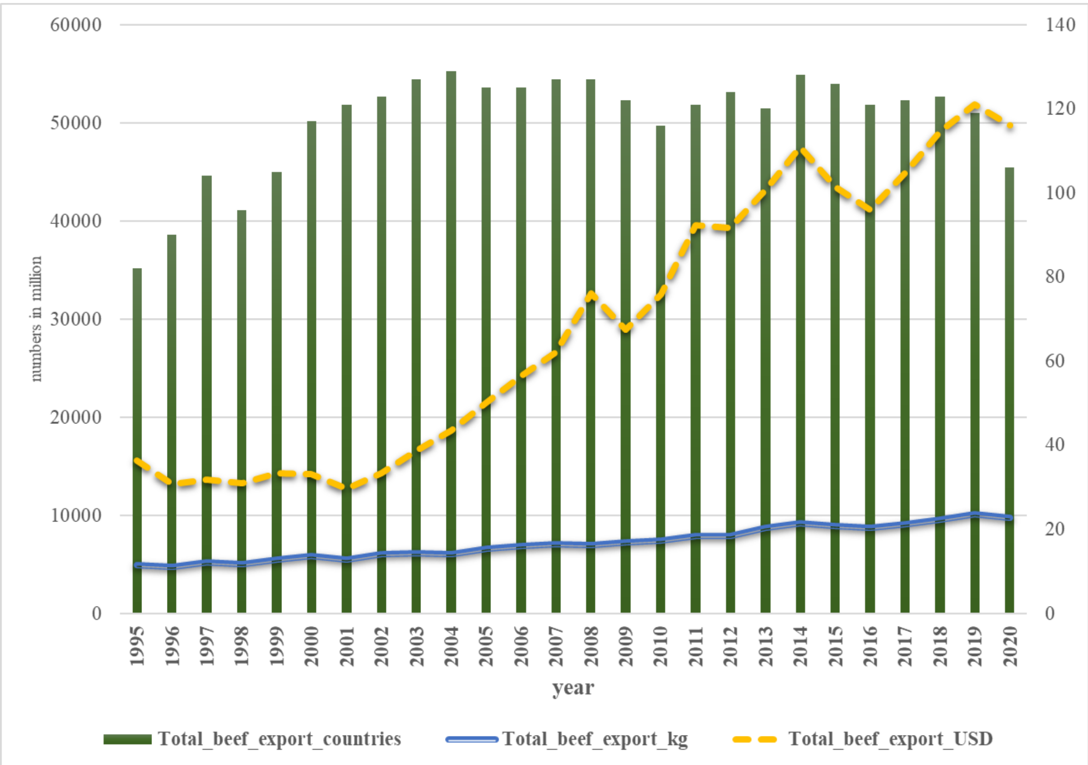


Figure 4.8: Total beef export to the world in terms of quantity, value, and no. of countries over the years 1995-2020

DAIRY EXPORT MARKET SHARE

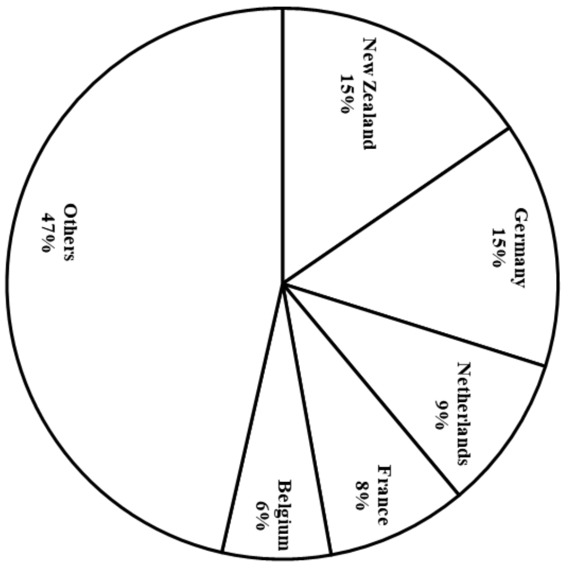


Figure 4.9: Dairy export market share of top five countries computed on average dairy export to the world from years 1995-2020

SHEEP EXPORT MARKET SHARE

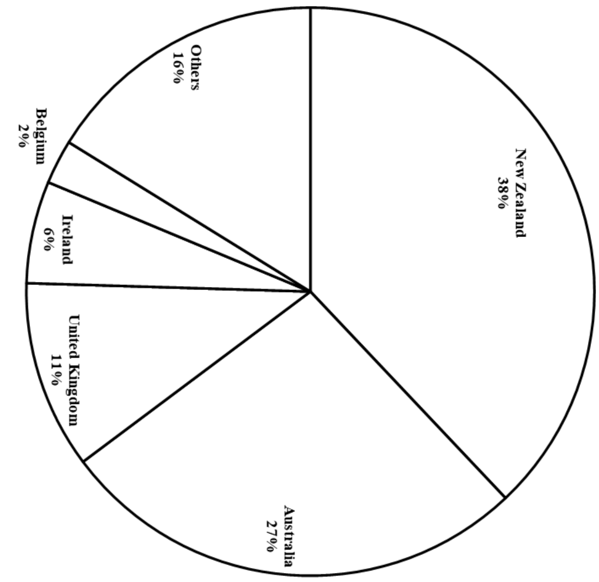


Figure 4.10: Sheep export market share of top five countries computed on average sheep export to the world from years 1995-2020

BEEF EXPORT MARKET SHARE

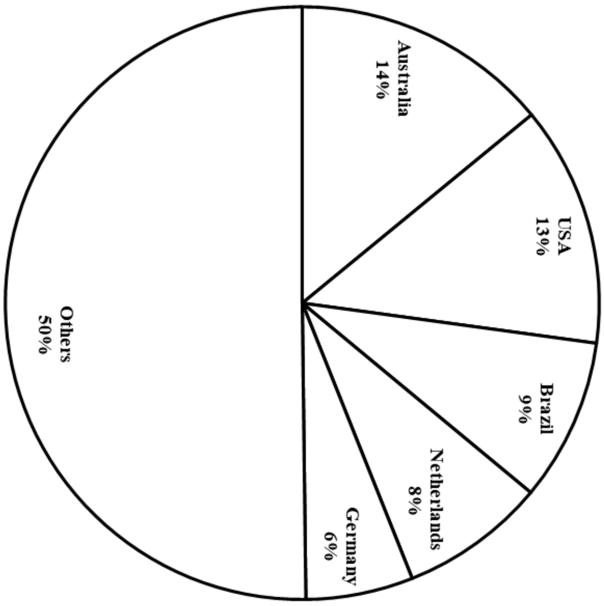


Figure 4.11: Beef export market share of top five countries computed on average beef export to the world from years 1995-2020

4.11.2 APPENDIX - TABLES

Table 4.8: Sectoral classification of products and their HS code description

Sector	HS Code	Sub Code	Description
Dairy	0401		Milk and cream; are not concentrated nor containing added sugar or other sweetening matter
		040110	Of a fat content < 1% (by weight)
		040120	Of a fat content > 1% but < 6% (by weight)
		040130	Of a fat content > 6% (by weight)
		040140	Of a fat content > 6% but < 10% (by weight)
		040150	Of a fat content > 10% (by weight)
	0402		Milk and cream; concentrated or containing added sugar or other sweetening matter
		040210	In powder, granules or other solid forms sweetened, fat content < 1.5% (by weight)
		040221	In powder, granules or other solid forms unsweetened, fat content > 1.5% (by weight)
		040229	In powder, granules or other solid forms sweetened, fat content > 1.5% (by weight)
		040291	Other than in powder, granules or other solid forms unsweetened, concentrated
		040299	Other than in powder, granules or other solid forms sweetened, concentrated
Beef	0201		The meat of bovine animals; fresh or chilled
		020110	Carcasses and half-carcasses, fresh or chilled
		020120	Other cuts with bone in, fresh or chilled
		020130	Boneless cuts, fresh or chilled
	0202		The meat of bovine animals; frozen
		020210	Carcasses and half-carcasses, frozen
		020220	Other cuts with bone in, frozen
		020230	Boneless cuts, frozen
Sheep	0204		The meat of sheep or goats; fresh, chilled or frozen
		020410	Lamb carcasses and half-carcasses, fresh or chilled
		020421	Sheep carcasses and half-carcasses, fresh or chilled
		020422	Sheep and lamb other cuts with bone in, fresh or chilled
		020423	Sheep and lamb boneless cuts, fresh or chilled
		020430	Lamb carcasses and half-carcasses, frozen
		020441	Sheep carcasses and half-carcasses, frozen
		020442	Sheep and lamb other cuts with bone-in, frozen
		020443	Sheep and lamb boneless cuts, frozen
		020450	Goat meat, fresh, chilled or frozen

Table 4.9: List of countries in our sample classified as high-income or middle-low-income group countries based on world bank classification and their respective market share in the trade of dairy, sheep and beef.

S.No.	Country	Income Group	Classified as	Market share in trade (%)		
				Dairy	**Sheep**	**Beef**
1	Australia	High income	High-income group countries	4.87	26.83	14.04
2	Austria			1.73	0.02	1.23
3	Belgium			6.36	2.52	2.26
4	Canada			0.51	0.03	4.87
5	Chile			0.32	0.46	0.07
6	Croatia			0.07		0.04
7	Cyprus			0.01		
8	Czech Republic			1.39		0.07
9	Denmark			2.25	0.10	1.42
10	Estonia			0.32	0.01	0.01
11	Finland			0.32	0.01	0.07
12	France			8.25	1.62	4.55
13	Germany			14.44	1.02	5.84
14	Greece			0.03	0.27	0.02
15	Hungary			0.41	0.05	0.13
16	Iceland			0.003	0.21	
17	Ireland			2.17	5.81	5.84
18	Italy			0.25	0.28	1.52
19	Japan			0.04		0.15
20	Latvia			0.29		0.04
21	Lithuania			0.72		0.20
22	Netherlands			9.08	1.71	7.93
23	New Zealand			15.41	37.95	4.86
24	Norway			0.01	0.01	0.01
25	Poland			2.10		1.82
26	Portugal			0.74	0.04	0.05
27	Singapore			0.83	0.04	0.04
28	Slovakia			0.41		0.03
29	Slovenia			0.36		0.05
30	South Korea			0.03		0.01
31	Spain			1.52	2.47	1.77
32	Sweden			0.64	0.03	0.04
33	Switzerland			0.22		0.004
34	USA			4.30	0.34	13.13
35	United Kingdom			3.57	10.70	1.09
36	Uruguay			1.00	1.13	2.93
Total market share of high-income group countries				**84.97**	**93.66**	**76.13**
37	Argentina		Middle - lo	2.13	0.26	3.66

38	Brazil	Upper middle income		0.41		8.87
39	China			0.34	0.62	0.20
40	Colombia			0.13		0.31
41	Costa Rica			0.21		0.17
42	Ecuador			0.02		
43	Macedonia				0.29	
44	Malaysia			0.73		0.03
45	Mexico			0.30		1.05
46	Moldova				0.05	0.05
47	Paraguay					1.46
48	Romania			0.08	0.22	0.03
49	Thailand			0.42		
50	Turkey			0.12	0.09	0.01
51	Bolivia	Lower middle income		0.05		
52	Egypt			0.07	0.01	0.003
53	El Salvador			0.01		
54	India			0.32	1.14	4.49
55	Indonesia			0.27		
56	Morocco			0.003		
57	Nicaragua			0.12		0.70
58	Zambia			0.01		0.0004
59	Niger	Low income		0.01		
60	Uganda			0.06		
Total market share of middle-low-income group countries				**5.81**	**2.68**	**21.03**
Total market share of all countries in the sample[29]				**90.79**	**96.34**	**97.17**

Table 4.10: SPEI Classification

Category	**Classification**	**SPEI**
Extreme wet	Wet	SPEI ≥2.0
Severe wet		1.5 ≤ SPEI < 2
Moderate wet		1 ≤ SPEI < 1.5
Normal	Normal	-1 < SPEI < 1
Moderate drought	Drought	-1.5 < SPEI ≤ -1.0
Severe drought		-2.0 < SPEI ≤ -1.5
Extreme drought		SPEI ≤ -2.0

[29] The sum is not 100 as it counts for the total market share of all countries from our sample only. The difference of this number from 100 shows the market share of countries excluded from our sample and are not regular exporting countries.

Table 4.11: Drought effects on export quantities and export values of the beef sector from all, medium-low-income and high-income countries (Excluding the USA)

Indicators	**All Countries**		**Medium-low-income Countries**		**High-income Countries**	
	Log Qty (kg)					
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Drought (t)	-0.23*** (0.03)	-0.24*** (0.03)	0.07 (0.06)	0.06 (0.07)	-0.37*** (0.01)	-0.37*** (0.02)
Drought (t-1)		-0.22** (0.03)		-0.02 (0.06)		-0.27*** (0.02)
Obs	1,248	1,200	390	375	858	825
n	48	48	15	15	33	33
t (years)	26	25	26	25	26	25
	Log Val (USD)					
Drought (t)	-0.004 (0.02)	-0.03 (0.02)	0.33*** (0.04)	0.35*** (0.05)	-0.20*** (0.01)	-0.22*** (0.01)
Drought (t-1)		0.01 (0.02)		0.29*** (0.05)		-0.15*** (0.01)
Obs	1,248	1,200	390	375	858	825
n	48	48	15	15	33	33
t (years)	26	25	26	25	26	25

Notes: Each specification includes country and year fixed effects. Standard errors in parentheses.
** p<0.1, ** p<0.05, *** p<0.01*

Table 4.12: Wider drought effects on export quantities and export values of the dairy sector from all, medium-low-income and high-income countries (if a country holds more than 50% agricultural land)

Indicators	**All Countries**		**Medium-low-income Countries**		**High-income Countries**	
	Log Qty (kg)					
Model	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Drought (t)	-0.41*** (0.04)	-0.36*** (0.05)	-0.90*** (0.05)	-0.85*** (0.04)	-0.20*** (0.02)	-0.14*** (0.02)
Drought (t-1)		-0.20*** (0.05)		-0.66*** (0.04)		-0.38*** (0.02)
Obs	1,482	1,425	546	525	936	900
n	57	57	21	21	36	36
t (years)	26	25	26	25	26	25
	Log Val (USD)					
Drought (t)	0.10*** (0.02)	0.09*** (0.03)	-0.03 (0.04)	-0.01 (0.03)	0.04*** (0.01)	0.06*** (0.01)
Drought (t-1)		0.05 (0.03)		-0.24*** (0.03)		-0.04*** (0.01)

Obs	1,482	1,425	546	525	936	900
n	57	57	21	21	36	36
t (years)	26	25	26	25	26	25

Notes: Each specification includes country and year fixed effects. Standard errors in parentheses.
** p<0.1, ** p<0.05, *** p<0.01*

Table 4.13: Wider drought effects on export quantities and export values of sheep sector from all, medium-low-income and high-income countries (if a country holds more than 50% agricultural land)

Indicators	**All Countries**		**Medium-low-income Countries**		**High-income Countries**	
	Log Qty (kg)					
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Drought (t)	-0.25*** (0.01)	-0.26*** (0.01)	0.03 (0.18)	-0.06 (0.16)	-0.37*** (0.01)	-0.37*** (0.01)
Drought (t-1)		-0.19*** (0.01)		0.08 (0.16)		-0.31*** (0.01)
Obs	858	825	208	200	650	625
n	33	33	8	8	25	25
t (years)	26	25	26	25	26	25
	Log Val (USD)					
Drought (t)	-0.14*** (0.01)	-0.14*** (0.01)	-0.08 (0.17)	-0.08 (0.18)	-0.07*** (0.01)	-0.07*** (0.01)
Drought (t-1)		-0.04** (0.02)		-0.21 (0.18)		0.04*** (0.01)
Obs	858	825	208	200	650	625
n	33	33	8	8	25	25
t (years)	26	25	26	25	26	25

Notes: Each specification includes country and year fixed effects. Standard errors in parentheses.
** p<0.1, ** p<0.05, *** p<0.01*

Table 4.14: Wider drought effects on export quantities and export values of the beef sector from all, medium-low-income and high-income countries (if a country holds more than 50% agricultural land)

Indicators	**All Countries**		**Medium-low-income Countries**		**High-income Countries**	
	Log Qty (kg)					
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Drought (t)	-0.41*** (0.03)	-0.33*** (0.04)	-0.31*** (0.06)	-0.31*** (0.10)	-0.34*** (0.02)	-0.31*** (0.01)
Drought (t-1)		-0.48*** (0.04)		-0.43*** (0.10)		-0.38*** (0.01)
Obs	1,274	1,225	390	375	884	850

n	49	49	15	15	34	34
t (years)	26	25	26	25	26	25
	Log Val (USD)					
Drought (t)	0.05 (0.03)	0.00 (0.03)	0.13*** (0.04)	0.14*** (0.04)	-0.17*** (0.01)	-0.18*** (0.01)
Drought (t-1)		-0.02 (0.03)		0.02 (0.04)		-0.20*** (0.01)
Obs	1,274	1,225	390	375	884	850
n	49	49	15	15	34	34
t (years)	26	25	26	25	26	25

Notes: Each specification includes country and year fixed effects. Standard errors in parentheses.
** p<0.1, ** p<0.05, *** p<0.01*

Chapter 5: **Conclusion**

The main purpose of this dissertation was to provide quantitative insights into the financial and economic impact of droughts. Therefore, this dissertation presented three lines of empirical studies investigating the impacts of drought events on farmers' financial needs, banks' balance sheets and on worldwide export quantities and values of dairy, sheep and beef. The findings and implications from these studies are as follows.

First, we investigated if the farms' borrowings, use of equity funding, and associated costs change during or after droughts. Our results show a statistically significant increase in short-term and long-term debts, equity, and the cost of debt for dairy farms in the aftermath of droughts. The results show a statistically significant negative impact of droughts on the profitability of dairy farming, and a negative impact of only severe drought conditions on the profitability of sheep and beef farms. Furthermore, the occurrence of consecutive droughts increases their impact on farms' capital structure. Dairy farms face more financial strain compared to sheep/beef farms during and after droughts and need to rely on both equity and debt financing. The results by farm size categories show that it is the small dairy farms that rely more on equity funding and short-term borrowing during and after drought conditions. Large dairy farms appear financially more resilient to drought conditions, whereas the large sheep/beef farms remain active borrowers during and after different levels of drought conditions.

We tested one link in the chain from droughts to financial fragility. We examined the link between droughts to an increase in equity/debts in a potential causal chain of droughts, debts and productivity/ performance, and then systemic lenders (banks) fragility. Future research may empirically explore the next stages in this causal chain from debt/equity to farm financial performance and banking sector profitability; as in most cases, it is banks that are the main source of lending for farms, in New Zealand and elsewhere.

Secondly, we analysed the frequency and intensity of droughts as potential determinants of agricultural NPLs in the banking sector. The previous literature includes a line of studies examining micro and macroeconomic factors as determinants of NPLs, while largely ignoring environmental factors, despite the discussions about climate change as a potential risk for financial institutions. There is also only limited evidence exploring the association between climate change and the credit risk of banks. Analysis of the regional occurrences of droughts and NPLs shows that droughts led to increased sectoral NPLs for banks, deteriorating their loan quality. All this suggests that drought risks should be incorporated into banking stress testing exercises and that lenders could potentially consider loan loss provisions against their sectoral lending in drought-prone areas.

This research can further be extended, if additional data become available, to the connections between different types of loan portfolio exposures to various environmental risks. For example, whereas agricultural loans are vulnerable to droughts, home loans may be more vulnerable to floods. This analysis can help policymakers and banks to incorporate a wider range of portfolio-specific environmental risks in bank stress testing.

Thirdly, our findings suggested that droughts, over the period considered, have a significant impact on agricultural exports (dairy, sheep, and beef). Droughts significantly reduce dairy export quantities from low-income countries, while they increase dairy export values for high-income countries. Exports of sheep and beef from high-income countries are found significantly vulnerable to droughts in terms of reducing export quantities, and values. Further, we observed from our results the percentage of reduction in export quantities is higher than the export values. Whereas the exports of beef from medium-low-income countries are found significantly beneficial to droughts in terms of increasing export values. The findings provide detailed evidence of how agricultural export of dairy sheep and beef patterns are vulnerable or beneficial to drought conditions, and they could be used in further projections considering droughts as a determinant of agricultural trade.

The research presented in this dissertation is relevant to our concerns that climate change is modifying the likelihoods, durations and intensities of droughts and other natural hazards as they are experienced in New Zealand and worldwide. However, there is a lot of uncertainty in our knowledge concerning the onset and duration of droughts in general, and the impact climate change will have on these processes. The Intergovernmental Panel on Climate Change projects an intensification of the hydrological cycle, with more precipitation-related extremes (both extreme wet and extreme dry events). As such, we do not try and project the implications of our estimations for future impacts of climate change on farms' capital structure, banks' balance sheets and the world's trade through the drought channel. We leave these efforts for future research. This research can also be extended to test the impact of farm adaptation to drought risks. In particular, whether such adaptation can reduce financial stress.

Our study results suggest some policy implications. These can include encouraging investments in climate-resilient agriculture technology and infrastructure that can help farmers adapt to changing weather patterns and reduce the impact of droughts on their production. Implementing agricultural insurance programs to help farmers mitigate the financial losses from weather-related risks. Providing financial assistance to farmers in the form of low-interest loans, grants, or other forms of support to help them manage increased debt levels. Encouraging banks to undertake regular climate risk assessments to help identify and manage the potential impact of climate change on their lending portfolios. Developing climate-sensitive lending policies that take into account the potential impact of climate change on the ability of borrowers to repay their loans. Overall, these policy implications can help farmers and financial institutions manage their financial risks and continue to be productive and successful.