Final Report

AUSTRALIAN MEAT PROCESSOR CORPORATION

A statistical and econometric analysis of how weather impacts Australian livestock markets

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3. Abstract

This research examines the impact of weather on Australian cattle and lamb markets through theoretical economic modelling and statistical techniques. To measure the effect of weather on cattle and lamb markets independently, the research approach used a variable selection technique to search for the best weather variable, location, and time aggregation for explaining markets. The findings of these models reveal that in the short run, 25% of cattle and 22% of lamb price variability, respectively, is attributable to weather. The inclusion of grass-fed cattle production raises the attributable cattle price variability to 40%. Over the longer run, which allows for factoring in herd rebuilding and supply changes suggests that 54% and 32% of cattle and lamb price variability, respectively, can be linked to weather. These values likely underestimate the weather's full impact on prices. Statistical tools suggest limiting locations for better inference, but this precision restricts the variability in prices attributable to weather. Prices were statistically shown to be the next largest factor in driving price variability over time, however, this attribution would include factors such as demand, as well as serving as a catch-all for variables not directly included in the model. The study identifies monthly average rootzone soil moisture in southern Queensland and northern New South Wales as the primary weather variable and location for driving cattle markets, while monthly precipitation around South Australia Gulf and southern Victoria is explanative for lamb markets. These insights underscore the importance of weather in market dynamics and highlight the need for improved forecasting and information dissemination to enhance decision-making among producers, processors, and policymakers, as well as policies that support minimizing processing constraints during periods of increased supply.

4. Acknowledgments

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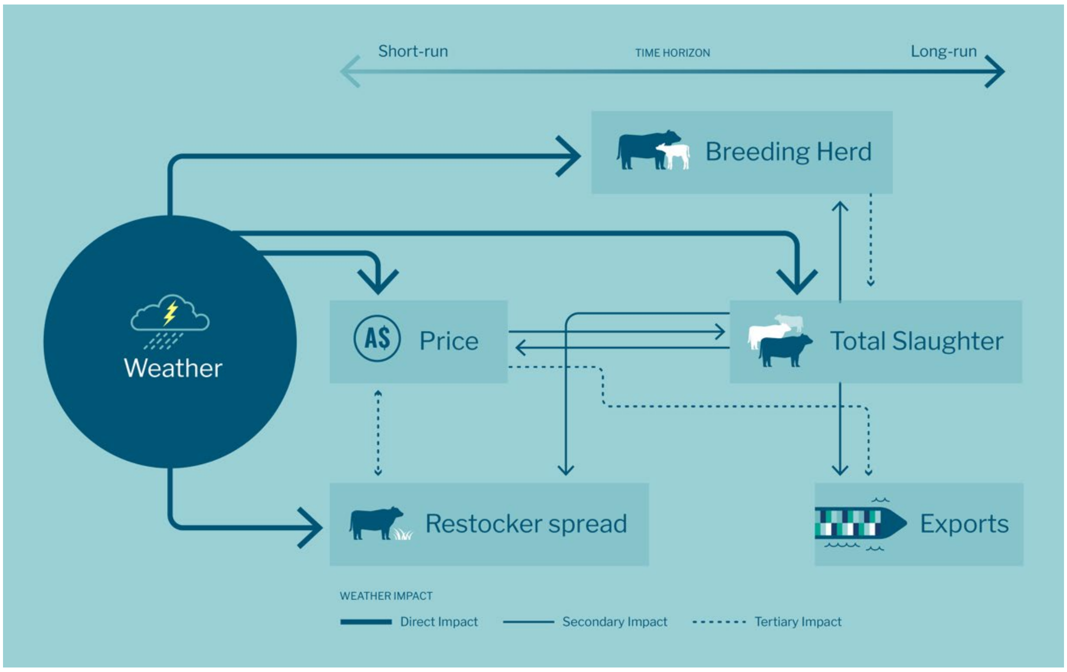
5. Executive Summary

Although producers, policymakers, and others generally recognize the sensitivity of cattle and lamb markets to weather, the specifics- how, why, and to what degree- remain less understood. This research project examines these three questions through theoretical economic models and statistical analyses to assess weather’s impact. By defining the key economic incentives of producers and processors in the cattle and lamb markets and by statistically analysing historical data, the report sheds light on the behaviours of economic agents and explains how weather influences their decisions. This understanding is crucial for producers and policymakers concerned about market dynamics and competition. Moreover, the research discusses that while weather is conceptually recognized for driving market conditions, breaking down weather's complexities into specific regions and variables is essential for effectively monitoring conditions and staying informed.

Below, Figure 1, is a visual summary of the effect of weather on cattle markets. In the short term, weather affects markets by altering the marginal costs of production. Meaning, when feed availability decreases, production costs rise, prompting producers to decide between keeping animals on grass, purchasing feed, or sending them to slaughter. These shifts move the supply curve. The supply shift is most apparent in the response of restockers, who's comparative advantage is tied to feed availability and must be responsive to changing growing conditions. The shift in the supply curve, particularly during times of drought, can push supply volumes beyond the processing capacity of the industry, which then drives down prices. Alternatively, when pasture is abundant, processors face increasing competition among themselves to seek animals for processing in order to keep their average processing costs low, given large fixed investments.

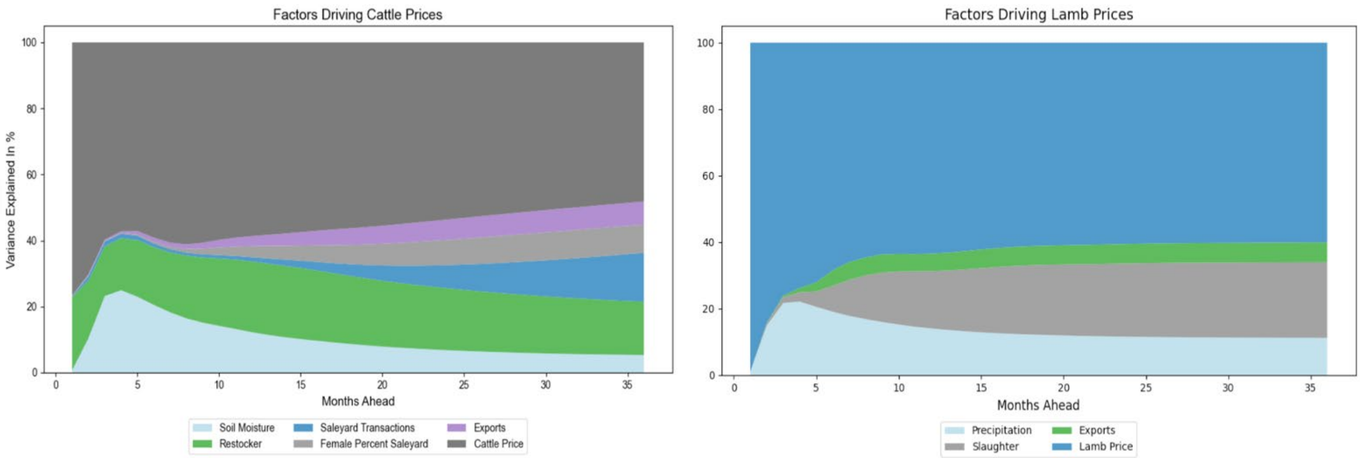
Figure 1. How Weather Impacts Cattle Markets



Over the medium to long run, the impacts from the short-term weather shocks build into larger and longer term outcomes, such as changes in the supply of breeding animals, which then directly impact how many animals are available for slaughter and exports. Export volumes are impacted by both the quantity of supply available and the relative competitiveness of the Australian sector to global markets.

To statistically measure these relationships between weather and markets, this report used a multivariate econometric model to account for the market dynamics and inter-relationship of multiple dependent variables over time. To measure the effect of weather on cattle and lamb markets independently, the research approach used a variable selection technique to search for the best weather variable, location, and time aggregation for explaining markets. This means that while there are a host of weather measurements, locations, and aggregations possible, the report narrowed in on the one location, measurement, and time aggregation to best explain markets. The report finds that 25% of cattle and 22% of lamb price variability in the short run is directly attributable to weather, presented in Figure 2. Further factoring in grass-fed cattle production to these numbers, which is directly impacted by weather, expands the explainable variability in cattle prices to 40% in the short run. Factor in the role of weather in driving herd rebuilding decisions and herd size, and roughly 54% and 32% of the price variability directly or indirectly can be attributed to weather for cattle and lamb prices, respectively. The results highlight that despite including a relatively limited number of variables used to explain a large and diverse market, 51% of the variability in prices over time can be explained and attributed to weather conditions and supply and demand factors.

Figure 2. Summary of Factors Driving Cattle and Lamb Prices

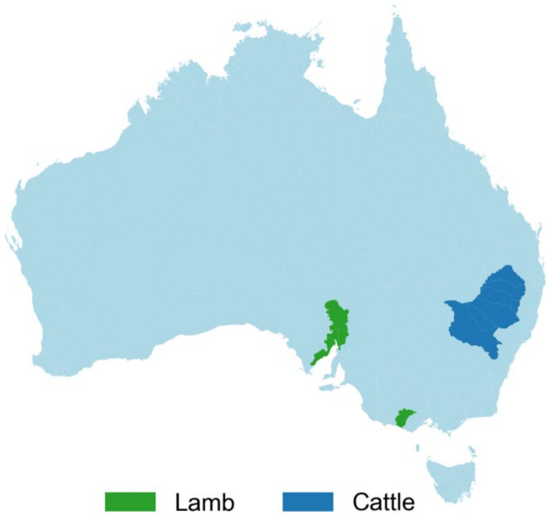


Notes: Presented above are the results of a Forecast Error Variance Decomposition (FEVD), which resulted from econometric models presented in greater detail in the report. The graphs present on the y-axis, out of 100 percent, how much price variability is attributed to the variables included in the model, as listed in the legend below. Larger regions of shading indicate larger percentages of price variability attributed to the variables. The time horizon at the bottom of the chart indicates the variability of each variable attributed to different time perspectives. For cattle prices, for example, the variability of prices from zero to the next six months is mostly attributable to price itself, restocker demand, and weather. The longer-term price variability is related to where cattle saleyard transactions, exports, and female breeding size uncertainty.

The figures highlight that price variability over time is largely attributable to price itself. This can be viewed in two ways: 1) the correlation of demand shocks over time captured through price movements, and 2) the price movement not directly attributed to the model's variables. Thus, the price variable may overstate its influence on price variability, neglecting other unaccounted variables. For instance, a flood causing price increases from shocks to market access is not linked to our weather variables, but would instead be attributable to price. This is because while we can observe the shock in one location at one point in time, statistically we cannot include variables across all locations and all points in time, and be able to attribute each change to just weather, particularly in a production system as vast as Australian cattle and lamb production. Therefore, the results here reflect how weather directly impacts markets in the short term and how these effects translate into long-term changes in herd size and slaughter availability. Accordingly, these results should be viewed as lower-bound estimates of the weather's full market impact.

The report finds monthly average rootzone soil moisture in the southern Queensland and northern New South Wales region within the Murray-Darlin Basin to be the strongest weather variable, location, and time aggregation for explaining cattle markets. For lamb markets, monthly precipitation in areas around the South Australia Gulf and southern Victoria were found to be the most explanatory. Both of these regions are highlighted in Figure 3. These locations for the cattle and lamb markets are near concentrations of dense animal populations. The results show, as well, that while no single location and variable can explain all interactions between weather and markets nationally, a singular measure of weather in a single region explains a large portion of the movements in cattle and lamb markets, even more than animal supply in the short run.

Figure 3. Statistically Selected Regions for Explaining Cattle and Lamb Markets



In addition to explaining how much the variability of prices can be attributed to weather, the methods present marginal effects of the impact of the weather variables on markets, and specifically of importance here, price. The results from the cattle models show that for every reduction in soil moisture of 1% in one month steer prices are lower by 2 c/kg. Conversely, improved weather allows producers to raise animals at reduced marginal costs, resulting in price increases as processors compete by raising bids for livestock. To consider a situation similar to a minor drought, where a persistent change in soil moisture occurs, such as a six-month decrease in soil moisture by 5%, is estimated to decrease saleyard steer prices by around 60 c/kg. More persistent and more dramatic changes in soil moisture would push the impacts even further.

These findings highlight the role of weather in driving changes in the short run through changes in the marginal costs of producers and how processing constraints impact the adaptability of markets to these shocks. Further, the research describes how these initial weather shocks feed into long-term volatility through processor competition to acquire animals and through restocker demand to produce animals more cheaply during periods of high feed availability. By recognizing this market structure, producers, processors, and policymakers can improve the welfare of all market participants by improving the availability of information to individuals to make decisions. Further welfare improvements can come from anticipating future supply conditions through accurate supply forecasts, and minimizing processing constraints during periods of supply increases that surpass the capacity of the processing industry.

The findings from this research may be used to better model and predict future animal supply conditions and their impact on price. This would help the industry stay efficiently proactive to future conditions. Further, this research highlighted how weather contributes to market conditions particularly when processing capacity is constrained. Research aimed toward predicting when and where constraints may occur, and efforts that would reduce those constraints, would help minimize the impact of shocks to regional markets that impacting national markets negatively.

6. Introduction

Food production and its prices are more volatile than other commodities (Jacks et al., 2011). Despite the known susceptibility of the agricultural supply chain to weather, price volatility and the stickiness of both high and low prices lead some to question the competitive nature of the food supply chain, particularly cattle and lamb markets (Chang and Griffith, 1998; Chung and Griffith, 2009; Hyde and Perloff, 1998). Through both theoretical and statistical frameworks, this report explains and measures the role of weather in driving Australian cattle and lamb prices.

While the role of weather on farmers' management of pasture and range conditions is frequently studied from the farm systems approach (Gillard and Monypenny, 1990), measuring the broader effects of weather on the aggregate market is less understood. The challenge in doing so stems from the fact that while weather outcomes have local impacts on individual decisions, the high correlation of weather across aggregate locations and the transmission of prices from regions to nationally means local effects manifest into macroeconomic outcomes (Morales et al., 2017; Williams and Bewley, 1993). From a statistical perspective, this means one would need a large number of historical data points to sufficiently identify the impact of the many local variables driving aggregate markets. This problem is amplified by the long time lag between local decisions and aggregate outcomes in livestock markets.

Research, as well as the popular discourse, on livestock markets, has tried to explain the complexity of these markets with a simplified concept referred to as "cattle cycle(s)" (Aadland, 2002; Jarvis, 1974; Mundlak and Huang, 1996; Rosen et al., 1994; Rucker et al., 1984). They suggest that the key to understanding cattle and lamb markets lies in recognizing whether the cattle or lamb herds are shrinking or rebuilding. This framework offers a simple theory and discussion of the factors driving markets. This theory, however, rests on the notion that distinct weather shocks transition the market between two binary states: shrinking and rebuilding, as well as that all producers observe the same shock across space and time. Relatedly, this cattle cycle theory often also rests on the cobweb theory of markets, which suggests naïve production decisions about future prices can lead the market into periods of booms and over-supply busts (Gouel, 2012; Nerlove, 1958). Though intuitive and valuable for partially explaining markets, it oversimplifies both the impact of weather and producer decision-making in driving outcomes. This is likely why recent research has struggled with identifying the presence of a cattle cycle definitively in data (Heilbron et al., 2025; Li and Shonkwiler, 2021).

Aggregation bias is a well-known feature of macroeconomic research, as it explains why a microeconomic understanding does not fully explain market behaviour at the country or other aggregate level (Brockmeier and Bektasoglu, 2014; Guvenen, 2011). Consider, intuitively, even if (weather) shocks were distributed evenly over land (say, Queensland (QLD) and New South Wales (NSW)) and weather was binary (drought or not drought), as assumed by the cattle cycle research, each producer would still respond differently because of their production circumstances. Some would react quickly, others slowly, and some not at all. Each producer faces their own set of constraints and decision framework. Weather shocks, however, are not uniform or binary. Weather and pasture conditions vary considerably across time and space (regions, states, and farms; years, months, weeks, days). Further, shocks do not just occur on the supply side but also on the demand-side, such as international trade. While as intuitive as the cattle cycle is, it oversimplifies the reality of markets for producers, processors, and consumers.

This research accordingly resolves these challenges by using time-series modelling to measure the delayed, direct and indirect impacts of factors driving the Australia cattle and lamb markets. To avoid the statistical problem of having too many weather variables, an iterative variable selection technique is used to identify the most important measures of weather for local cattle and sheep producing regions. As opposed to relying on rigid structural models that impose behaviour, the models recover the behaviour of the market through less restrictive assumptions based on data. Despite fewer restrictions, the results are consistent with a conceptual understanding of producer incentives driving the supply of animals in a predominantly grass or pasture-fed production system, as well as the constraints of a short-term processing capacity-constrained market.

This report provides insight to the structure of the market, as well as the role of policy in mitigating welfare losses in the event of exogenous market shocks, such as weather. Drawing on evidence from price stabilization research (Gouel, 2012), the report details how policy can improve market welfare by targeting inefficient market constraints, such as reducing transportation costs during drought. The report also reviews how certain policies aimed at improving market competitiveness can be both hazardous to animal welfare and hasten soil resource degradation.

6.1. Background: Role of Weather in Cattle and Lamb Markets

To understand how weather affects the decisions of producers and the outcomes of the market, it is useful to review production economic theory regarding the role of variable and fixed costs in driving decisions and how individual producer and processing constraints influence prices.

Without going into full detail, as has been explained by others (e.g. (Greenwood et al., 2018)), the critical decisions faced by Australian livestock producers revolve around breeding herd choices and deciding when to sell their animals, either to another agent for weight gain or for slaughter. When pasture conditions are plentiful, producers may opt to breed their females that are of breeding age, as production costs remain relatively low because many expenses are fixed (like land and capital).

During droughts or periods of scarce feed, producers evaluate the costs of maintaining their breeding stock and raising calves up to finished weight for slaughter. In severe conditions, producers may decide not just to hold back heifers for future breeding but also to cull their breeding animals since they would incur high expenses for sourcing alternative feed. Culling a breeding animal is a significant choice because a calf takes about two years to start breeding. Therefore, making a culling decision on a breeding cow not only halts this year’s calf production but also means that to restore the herd size back to its prior state requires retaining a female calf that might have otherwise been produced for slaughter.

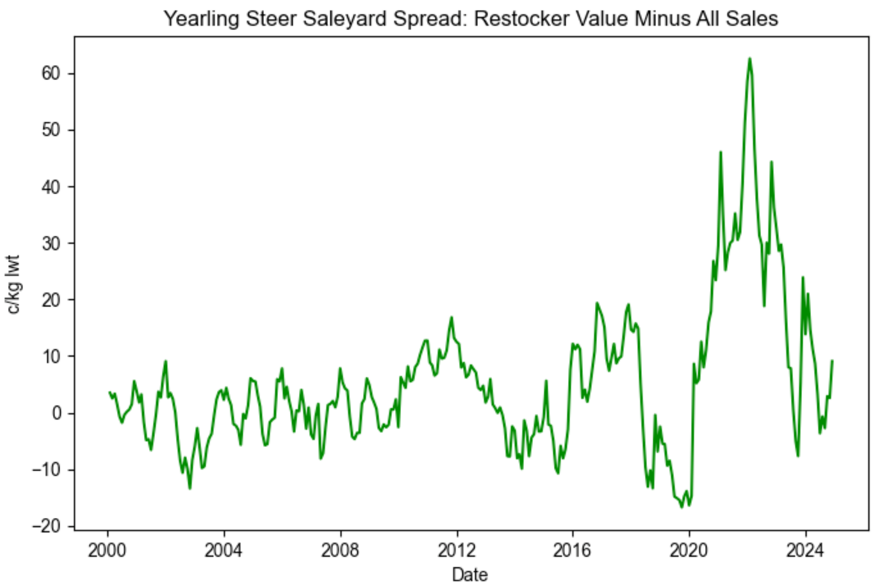
Thus, drought conditions that limit pasture availability impact the near-term supply of breeding animals for meat and the size of the animals intended for slaughter. Drought conditions set constraints on feed availability or significantly increase the marginal cost of weight gain, thereby potentially culling the animals before previously anticipated. In the medium to long term, the consequences of drought lead to a reduction in the supply of animals because there are fewer animals being bred. This pullback in supply can be even greater if pasture conditions improve, as calf producers can withhold heifers from slaughter to increase their own breeding stock. This phenomenon has been used to explain the existence of a cattle cycle, as changes in the breeding herd can influence outcomes for many years to come.

The generalization of the abovementioned herd dynamics fails to capture the decisions made between weaning and slaughter, which are particularly important in Australian cattle production. Australian cattle production differs from production in other regions, specifically the U.S., in that processed and slaughtered animals are more variable in size and feeding systems. The U.S. system is comparatively homogeneous because roughly 95% of the cattle are finished on grain at more similar weights. The variability in U.S. production is not so much if the animal ends up in a feedlot but at what weight it starts. This decision largely depends on the seasonality of weather and feed availability. If the cow-calf operator has access to available pasture or cheap feed, they can raise the animal to a higher feeder weight and sell a larger animal to the feedlot. Conversely, if the cow-calf operator faces lower availability of pasture or feed, or if winter conditions are expected to increase calf mortality, a smaller animal is sold to the feedlot, backgrounder, or finisher. The transfer value between the cow-calf producer, backgrounder, and the feedlot is greatly influenced by which party is responsible for putting weight on the animal. Competition in the market relates to which firm can add weight to the animal for the lowest cost, as they can bid cattle values up or down with changes in feed costs.

Though similar to this U.S. structure, Australian cattle production differs in large part due to the availability of pasture and its associated low feeding costs when available. In Australia, producers frequently raise their cattle entirely on grass from calving to slaughter. Although the production timeline is longer than in grain-fed systems, it remains economical because they face lower marginal costs throughout the cattle's lifespan, provided pasture is available. During much of the animal's lifespan, producers can sell to restockers or feedlots for further finishing before slaughter. A restocker is a market participant who purchases cattle/sheep/lamb and returns them to the farm. A restocker is competing with processors and feedlots for animals. The low marginal costs of raising animals on pasture and the differentiated processing system in Australia provide competition for animals throughout their lifespan.

To further illustrate how these pasture conditions impact prices and supply, as well as competition, consider Figure 4, which shows the price difference for yearling steers sold at saleyards to restockers and all transaction prices. The saleyard market, as reported by the Meat & Livestock Association (MLA), provides detail to not only the transactions but the sales prefix of the transaction, with restocker, feeder, and processor as the three largest prefix types. This level of detail is unavailable in other markets, such as the U.S., which has mandatory pricing at the finished cattle level. The MLA data allows us to highlight the competition for animals along the supply chain, as well as to focus on where most Australian cattle transactions occur.

Figure 4. Restocker Spread Indicates Pasture Availability[1]



If pasture availability is high, the restocker can pay more for animals than grain finishers or processors because of the lower marginal feed cost. You can see in the chart, how the spread is either a premium or discount to the average price. This spread effectively measures the marginal costs of production in restockers versus grain-fed systems. Accordingly, the chart highlights from 2020 through 2022, restockers paid a high premium above the rest of the market to purchase animals. By sending more animals to restockers, this accordingly reduced the supply of animals to feedlots and slaughter facilities, driving down

[1] Saleyard Yearling Steer Restocker Spread the difference in the average price (c/kg *L*wt) for steers sold to restockers minus all yearling steer transactions for QLD, NSW, VIC, and SA. Data from MLA (Meat & Livestock Australia, 2025a).

the supply of animals and driving up the cost of cattle for the whole market. Alternatively, from 2018 to 2019, when pasture availability was poor, restockers had little incentive to increase their production because they could not afford to feed animals. They continued to operate but at lower capacities to keep their business running but also not so much to permanently hurt their future pasture production caused by overgrazing. The balance and trade-off from the grass-fed production system create increased competition for animals between producer and processor.

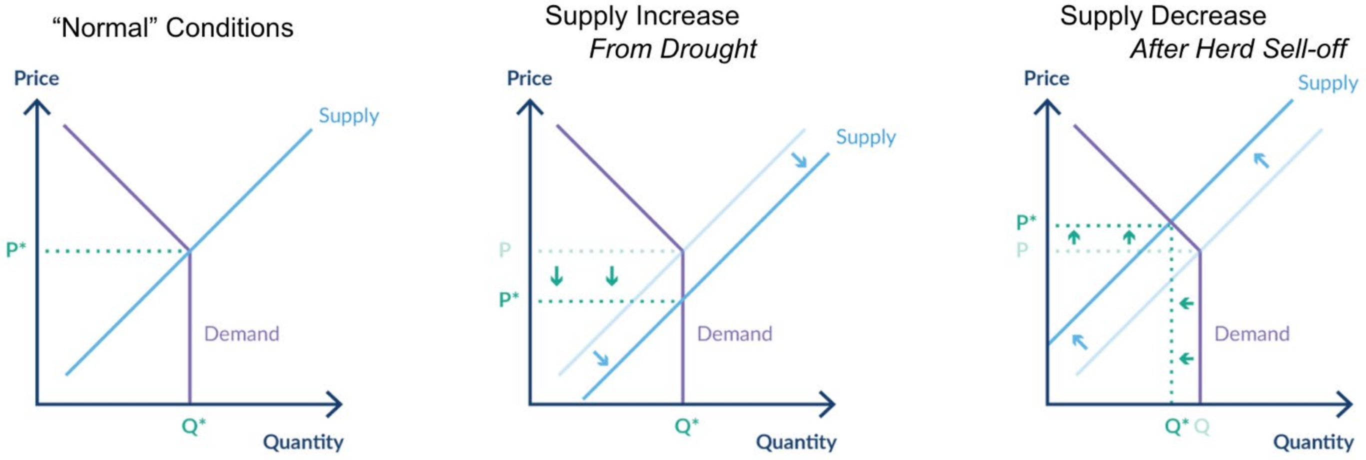
To evaluate the incentives of the processor and how weather and supply shocks impact the system, not just the producer, we must consider the fixed and marginal costs of processing animals for meat. Processing facilities are expensive to build and maintain, leading to high fixed investment costs that can amount to billions of dollars. Consequently, the scale of the facilities is to generate low marginal costs of production for each animal processed. This means that the cost of processing the 1,000th animal is not significantly different from that of processing the 999th animal. Intuitively, once the facility has been built, the labour hired, and the supply-chains developed, the cost to process one more animal is near zero until the processing constraint is met. The marginal cost of processing one animal beyond the facility's capacity is the cost of building a new facility.

Accordingly, the processor is most profitable when production is at or near the processing constraint (MacDonald, 2024; Paul, 2001). Every reduction in animal processed below the capacity constraint causes the average cost of each animal to increase, thereby hurting processor profitability. Processors will bid up animal values to ensure their facilities are supplied near their processing constraint (MacDonald et al., 2023). Thus, to remain profitable to compete against other processing firms, firms seek to lower their marginal processing costs through processing efficiency gains. In lowering marginal costs from more highly efficient processing, they can bid up cattle values and offer high wages to employees (Boyer et al., 2023), drawing workers and animals away from other processing competitors.

To understand how this competition and market structure of calf producers, breeders, restockers, feedlots, and processors impact cattle prices in the event of good or bad weather, consider the supply and demand charts presented in Figure 5. Moving from left to right, the left-hand chart is the short-run supply, demand, and equilibrium price of cattle in “normal” or well-balanced market. The processor demand is downward sloping until their processing constraint is met. This short-run market behaviour differs from standard supply and demand charts because if the short-run supply were to increase, such as in the event of a drought, the quantity supplied can not increase because processors can not process more animals despite an increase in the supply curve.

The role of processing capacity in setting market prices is significant not only because it illustrates how equilibrium prices decrease when the supply curve exceeds normal efficient levels, but also because it highlights that the quantity supplied, the actual number of animals processed, remains unchanged when the supply curve shifts to the right. This is because the equilibrium quantity can not surpass the industry's processing constraint. This is observed in the middle figure, where higher marginal production costs due to drought or high feed costs for the producer push the supply of animals to the right. Accordingly, the initial supply shift from weather or drought drives down equilibrium prices, but quantities remain the same, as processors facing fixed capacity cannot change how many animals they can process.

Figure 5. Dynamic Impact of Drought: Normal to Oversupply to Undersupply



The third subfigure (far-right) in Figure 5 presents a pullback of the supply curve to the left after the initial impact of drought is felt, as there are fewer available animals because calf producers culled their breeding animals instead of breeding more calves. This left-ward supply curve shift drives down the quantity of animals processed and the price of cattle higher. In this event, the processors bid up cattle values to try to fill shackling space. The supply reduction can be further shifted to the left if cattle producers decide to retain heifers for future breeding, as opposed to restockers, feeders, or processors. In Australian production, supply can also be further restricted by the restocker demand for calves, as those animals would have otherwise been sent to feedlots or processors. The different decisions available to producers along the supply chain create competition for animals.

Restockers are able to bid animals away from processors because of their low marginal feed costs. The degree to which weather impacts prices in the short-, medium-, and long-run relates to the slope of the supply and demand curve for finished cattle. The low-marginal costs of processing animals mean processors' demand curves are fairly inelastic (steeply pointed downward). This means large negative supply shocks will increase prices at a larger rate than the size of the shock. The elasticity of supply of cattle is likely highly inelastic in the event of drought, as limited feed availability forces the producers to send the animal to slaughter or face soil degradation concerns, as well starvation or animal welfare concerns. Alternatively, when pasture conditions are good, the competition from restockers and grass-fed production creates competition in the market for animals, thus pushing the elasticity of the cattle supply to processors higher. The degree to which weather impacts these markets is an empirical question that can only be answered through quantitative study. The following section of this paper dives into the data and methods to measuring the impact of weather on aggregate cattle and lamb markets.

7. Project Objectives

The project's objective was to use econometric modelling to determine the relative influencing factors driving fluctuations in cattle and lamb markets in Australia, particularly investigating the impact of weather and climate conditions.

8. Methodology

Though intuitive, research based on agricultural systems and the cattle cycle struggles to model markets because of the complexities of aggregation, a well-known challenge of macroeconomic research (Grunfeld and Griliches, 1960). We analyse the Australian cattle and lamb markets separately, using vector autoregression with exogenous variables (VARX).[2] This approach is flexible enough to capture key features of the markets while allowing for the flexibility to account for important system features and the role of weather in driving outcomes. Figures 4 and 5 present the endogenous variables for cattle and lamb markets, respectively. These initial figures do not present the exogenous weather data, which are discussed later in this section. All data are presented at the monthly average level and have been regionally restricted to only include saleyard transactions or slaughtering figures in the Eastern states and South Australia.

[2] A Vector Autoregression (VAR) is a statistical model used to capture the relationships between multiple dynamic data series by including each variable as a linear relationship between its past values and the past values of all other variables. These models consider only a limited number of variables because adding variables can lead to overfitting, which leads to less reliable results.

Figure 6. Cattle Markets Over Time[3]

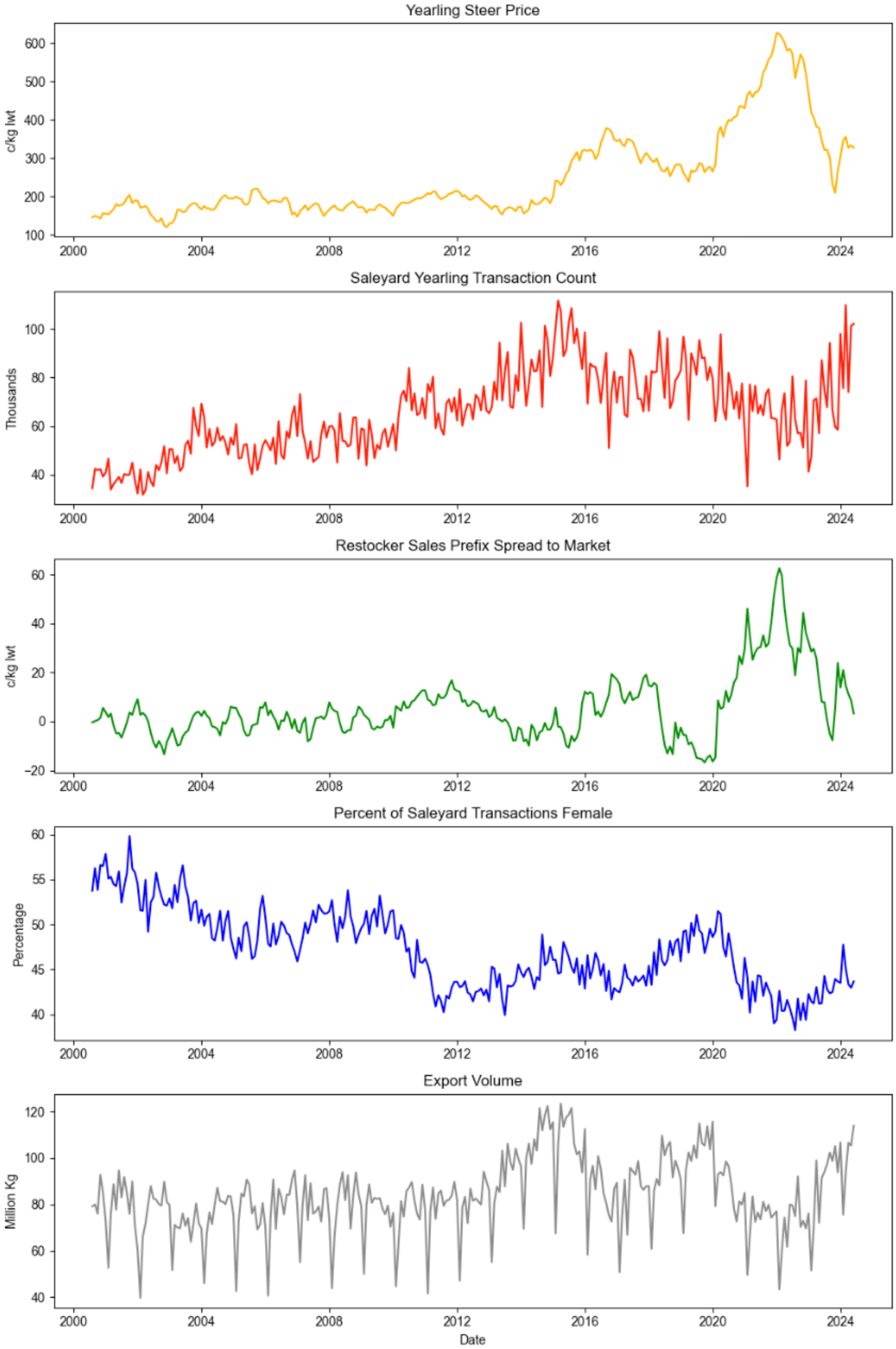


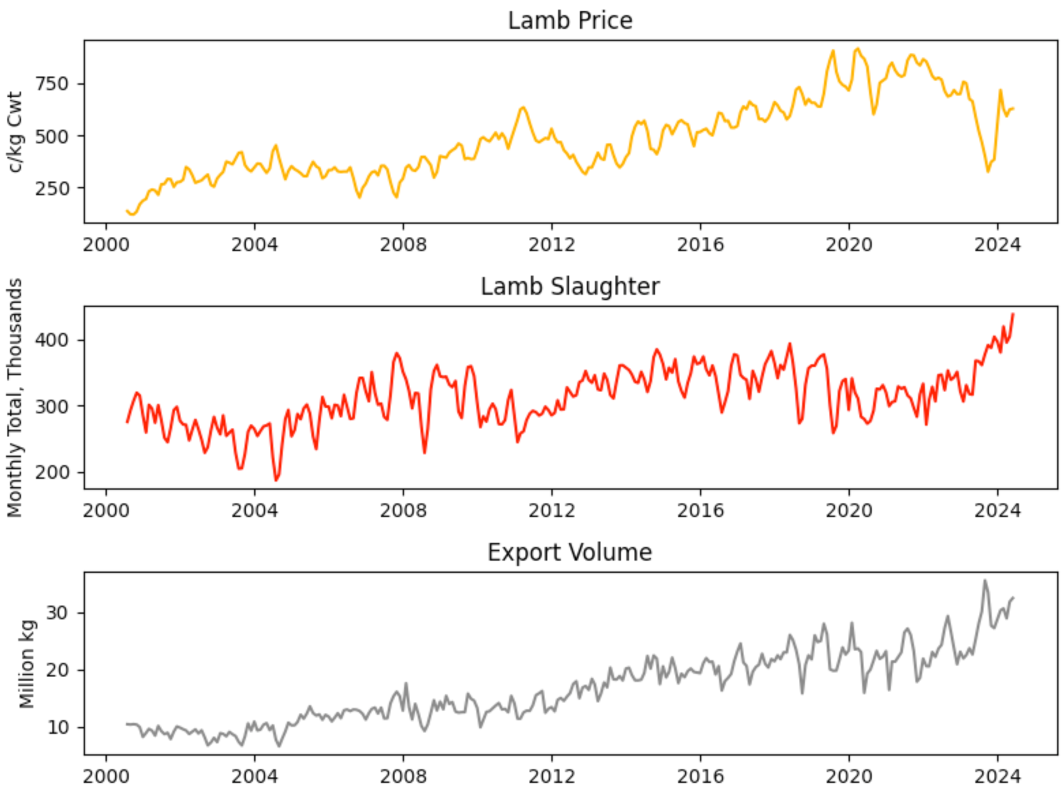
Figure 6 shows the saleyard yearling steer price for all sales prefixes, number of saleyard transactions for yearling steers and heifers, the difference in saleyard prices for restockers compared to the overall

[3] Yearling Steer Price is the monthly average price (c/kg Lwt) reported for saleyards in QLD, NSW, VIC, and SA. Saleyard Yearling Transaction Count is the monthly total, in thousands, steers and heifers in QLD, NSW, VIC, and SA. Restocker Sales Prefix Spread to Market is the difference in the average price for steers sold to restockers minus all yearling steer transactions. Percent of Saleyard Transactions Female is the heifer count over total yearling steer and heifers. Export volume is the monthly total beef and veal by weight (million kg) to all destinations. Data was obtained through the MLA (Meat & Livestock Australia, 2025a).

market, the percentage of saleyard transactions that are female, and the volume of beef and veal exports from Australia. Both price and quantity are measured through the saleyard transactions as these data are most visible to market participants, as it is presented at a high frequency and depth across saleyard locations. The spread of restocker price to market is included to reflect the varying marginal cost of production within the pasture and grass-fed market. When the restocker spread is positive, it is expected to be indicative of the supply of cattle for processors and grain-fed operations. The percent of saleyard transactions of female cattle is included to reflect the change in herd composition. While it is simplest to consider the herd being in a dichotomous culling or rebuilding phase, the herd composition in aggregates is a continuous variable that can dynamically change over time. Exports are an important component to demand as 67% of production was exported in 2023 (Meat & Livestock Australia, 2024).

Figure 7 presents the monthly average of the weekly slaughter of lambs as reported by the NLRS through MLA, the price of lamb, and seasonally adjusted volume of lamb and mutton exports.

Figure 7. Lamb Markets Over Time[4]



Notably, for measuring supply, we used saleyard transactions for cattle but slaughter for lamb markets. Saleyard data were chosen for cattle in part because we also measured the percent of heifers sold through that same transaction data, as well as both of our price series. This specification choice was also made because it is believed that the saleyard data are the most widely tracked data series by the market, thus most representative of market conditions. For lamb, we used slaughter data because, statistically, it better explained prices than saleyard transactions, though both were less explanatory than desired. This result is likely due to any measurement error in the reporting, as well as explained by market features not

[4] Lamb Price is the monthly average price (c/kg Cwt) reported for saleyards in QLD, NSW, VIC, and SA. Lamb slaughter total as reported by the National Livestock Reporting Service (NLRS), excluding western Australia and Tasmania. Export volume is the monthly total lamb exports by weight (million kg) to all destinations. All data were obtained via the MLA (Meat & Livestock Australia, 2025b).

captured in the data. For example, processing numbers tend to decline in December and January, but prices do not spike from the lower production number. This market intuition, where both producers and processors plan around these holiday time periods, is often lost in the data and can partially explain any limited role of the supply variables in explaining prices in the results section of the report.

Weather is treated as exogenous to the rest of the variables in the system of equations, and is therefore not presented in the above figures. Quantifying the effect of weather on the market is crucial for the research, as weather is a driving factor in these markets. Though intuitive, measuring the impact of weather is challenging because of the many ways it is defined and measured. From temperature to precipitation to evapotranspiration and more, there are numerous ways to measure weather as it relates to agriculture. Further, because weather is continuously measurable in space and time, it must also be aggregated in multiple dimensions.

For example, the researcher or practitioner could define and measure weather as an hourly precipitation total from one weather gauge. Weather can also be measured as the average temperature for an entire state at the annual level. Both measurements, an hourly rain gauge or annual state temperature, provide data that can be used to model cattle or lamb markets. Which variable to use, or even both, is a statistical question for defining the best way to measure cattle markets and which weather variable(s) drive markets. No single weather variable will perfectly encapsulate all of the nuanced effects of weather on production decisions across the country. However, by selecting one location and measurement, we can better understand the causal relationships between weather and markets. In the appendix, we also expand the consideration of weather variable selection to more than one location and measurement to multiple. This is because while selecting a single location is needed for defining causal relationships, the expansion to evaluate multiple locations and measurements can be used to measure the sensitivity of our models to specification choices related to the limitations of trying to explain the entirety of weather on markets. Accordingly, this is also beneficial for understanding the potential explainability of the variability of prices to weather. The following section outlines our variable selection process for determining which weather measurements and locations to consider.

8.1. Selecting Weather Variables: Measurement, Location, and Time

Our approach to selecting the best variable for explaining the impact of weather on cattle and lamb markets uses an iterative variable selection technique using information criteria (Akaike, 1998, 1981; Schwarz, 1978). We sourced data from the Australian Water Outlook (Bureau of Meteorology (BOM), 2025), which is reported daily across two-hundred and nineteen regions and every state for fourteen different weather measurements. The fourteen weather measures are presented below in Table 1. All measurements were aggregated to the monthly average level to match the frequency of the market variables. Additionally, weather data were aggregated to three, six, and twelve-month averages to allow for the potential cumulative effects of weather across months. In total, this provided 12,264 potential choices for weather variables to include.

Table 1. Australian Water Outlook (AWO) Weather Variables

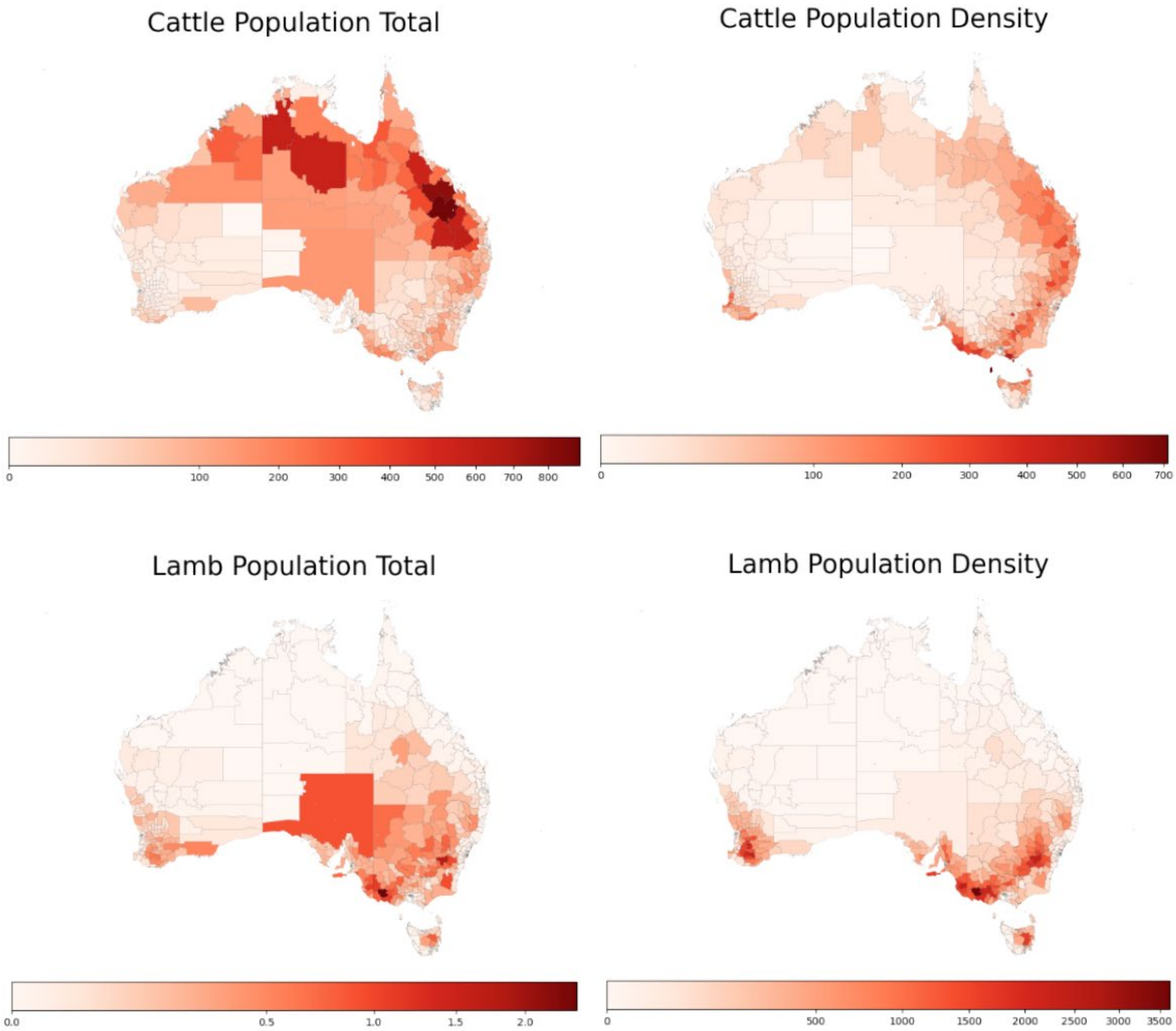
Weather Measurements
Areal potential evapotranspiration, mm
Deep drainage, mm
Deep soil moisture (1-6m depth), mm
Lower soil moisture (0.1-1m depth), % full
Modelled actual evapotranspiration, mm
Modelled potential evapotranspiration, mm
Open water evaporation, mm
Precipitation, mm
Reference crop evapotranspiration - Short, mm
Reference crop evapotranspiration - Tall, mm
Rootzone soil moisture (0-1m depth), % full
Runoff, mm
Synthetic pan evaporation, mm
Upper soil moisture (0-0.1m depth), % full

A VARX model that includes the most recent six data points for each endogenous variable was estimated iteratively with each potential weather variable. Weather is treated as an exogenous variable in the time-series model, including the current period level and six lags to match the lag length of the endogenous variables. Lags of the weather variable were included to match the dynamics of the endogenous variables, as well as allow for the potential of delayed dynamic response. The inclusion of weather lags supports the estimation if market responses to weather are delayed, as well persistent. The Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) values for each run of the model were stored to measure which variable best explains changes in the endogenous variables. Results with lower Information Criteria (IC) values are considered better variables as they explain a greater percent of the variability of the endogenous variables.

Iterating over all possible weather variables provides a method to not only finding the best weather variable to include but also a quantifiable tool for comparing the strength of the explanatory power of each weather variable to each other. For example, the AIC scores provide a ranking of weather measurement and location for each market. This ranking and relative comparison indicate to practitioners the comparative difference in monitoring multiple locations. These results can be helpful for not just quantifying the impact of weather on markets in this report, but also provide the basis for visualizations beneficial for market participants to understanding where to focus attention with respect to weather and production.

Figure 8 shows the density of cattle and lamb production and total population across Local Government Areas (LGA) (Australian Bureau of Statistics, 2023). While the total population of animals produced within a region is informative, it can be misleading if areas vary in size. Accordingly, the figure presents populations in totality at the LGA level, as well as the animal density for each LGA. Both viewpoints on production are valuable to understanding how weather at the river region level correlates with markets. The figure shows that cattle production is predominant in northern and eastern states. Cattle population density tends to wrap around the eastern coastline just inland enough away from but close to human populations. Lamb production is predominant in southern regions that include Victoria (VIC), NSW, and South Australia (SA), as well as southwestern Western Australia (WA).

Figure 8. Cattle and Lamb Population Total & Density[5]



While the paper's results focus on how much of the market variability can be attributed to one weather variable and location, we present visualizations of how the market explainability of weather varies by location, time aggregation, and weather measurement. The following set of figures visualize how, while one variable might be found to be the best candidate for explaining market variability, often there are others that could have also been selected but just fell short of the same explanatory power. The statistical differences are important to recognize but also the correlation and regional visualizations highlight to practitioners important regions to track when evaluating where weather is most likely to impact market conditions.

5 Note that the scale axis of the colors is presented non-linearly to emphasize the production variation across each region. Data were obtained from the Australian Bureau of Statistics (ABS) data on regional Local Government Areas (LGAs) for 2021. Counts for each LGA were the total meat cattle and total sheep and lambs by LGA. The density is calculated by dividing the total cattle (sheep and lambs) by 1,000 hectares. The total population is made up of units of thousand cattle and million sheep.

Figure 9 presents the AIC results for the cattle model for evaluating the explanatory power of precipitation by region and time aggregation. We initially present precipitation here since it is the most frequently cited driver behind market changes. The darker shading of the regions in the chart highlight a stronger explanatory power of the area and time aggregation. Shading is the difference in the AIC to the best location, weather variable, and time aggregation. The visual below shows the monthly (Figure 9: top-left) and twelve-month (Figure 9: bottom-right) time aggregations, as opposed to three-month and six-month, tended to show greater explanatory power, as measured by AIC. These time period aggregations also appear to show a greater contrast between the regions within the Murray-Darling Basin and all other regions, highlighting how time aggregation is important not just conceptually but also how aggregation specification choices might unknowingly correlate with other factors that could reduce explanatory power.

Figure 9. Strength of Weather Measurement and Region for Explaining Cattle Markets

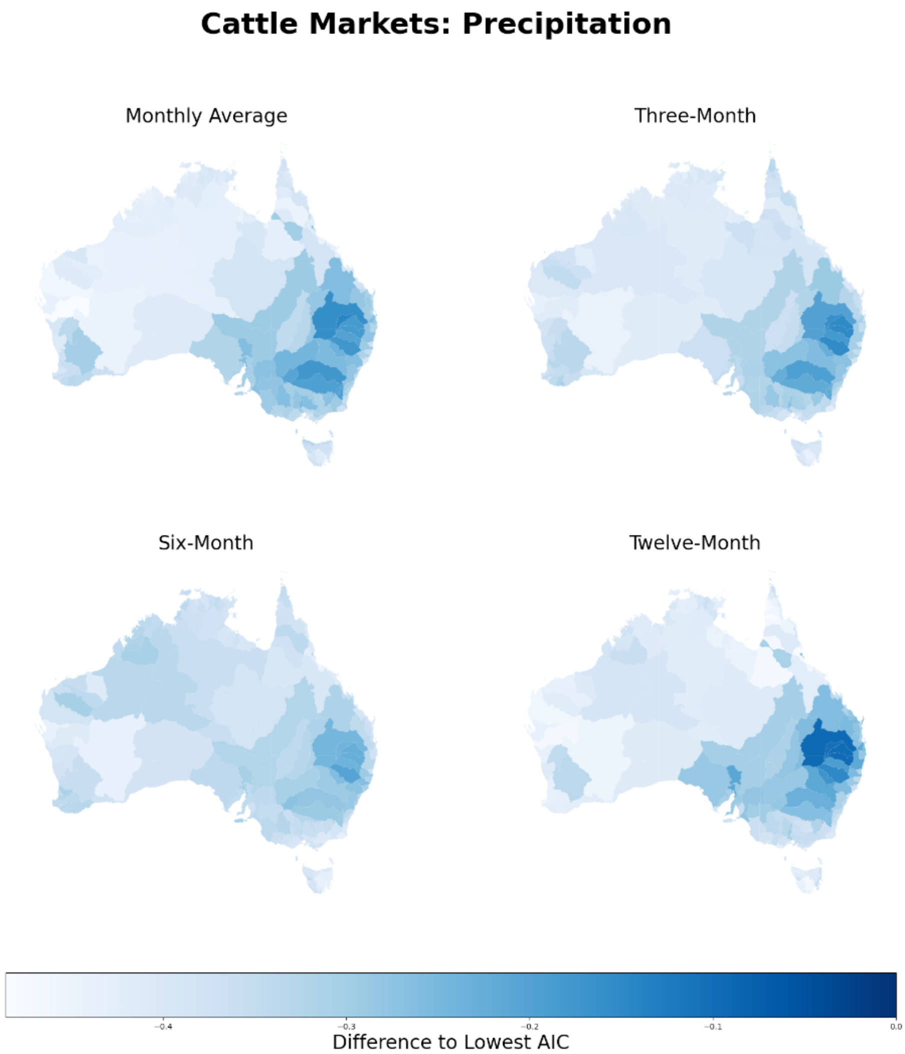


Figure 10 presents a similar graphic as above but examines the results for root zone soil moisture in explaining cattle market variability. This variable was presented as opposed to one of the other ten weather measurements because it included the singular river region, weather variable, and time aggregation that was found to be best for explaining cattle markets: this was the Namoi River region within the Murray-Darling Basin, averaged at the monthly level. The intensity of the shading of the monthly average root zone soil moisture highlights a strong explanatory power for the variable, as well as a strong correlation to neighbouring regions. The more a variable correlates with other similar regions, while not correlating with extraneous areas or weather measurements, the clearer the signal it is for explaining markets. This feature is crucial to consider when evaluating variable selection because if we limit the variable set to just one location, due to standard econometric properties, the one location selected indirectly measures all variables and locations that also correlate with it and the outcome variable. While precipitation tends to correlate more broadly with many regions, the rootzone soil moisture appears to be more closely targeted to large and dense cattle-producing areas.

Figure 10. Strength of Rootzone Soil Moisture and Region for Explaining Cattle Markets

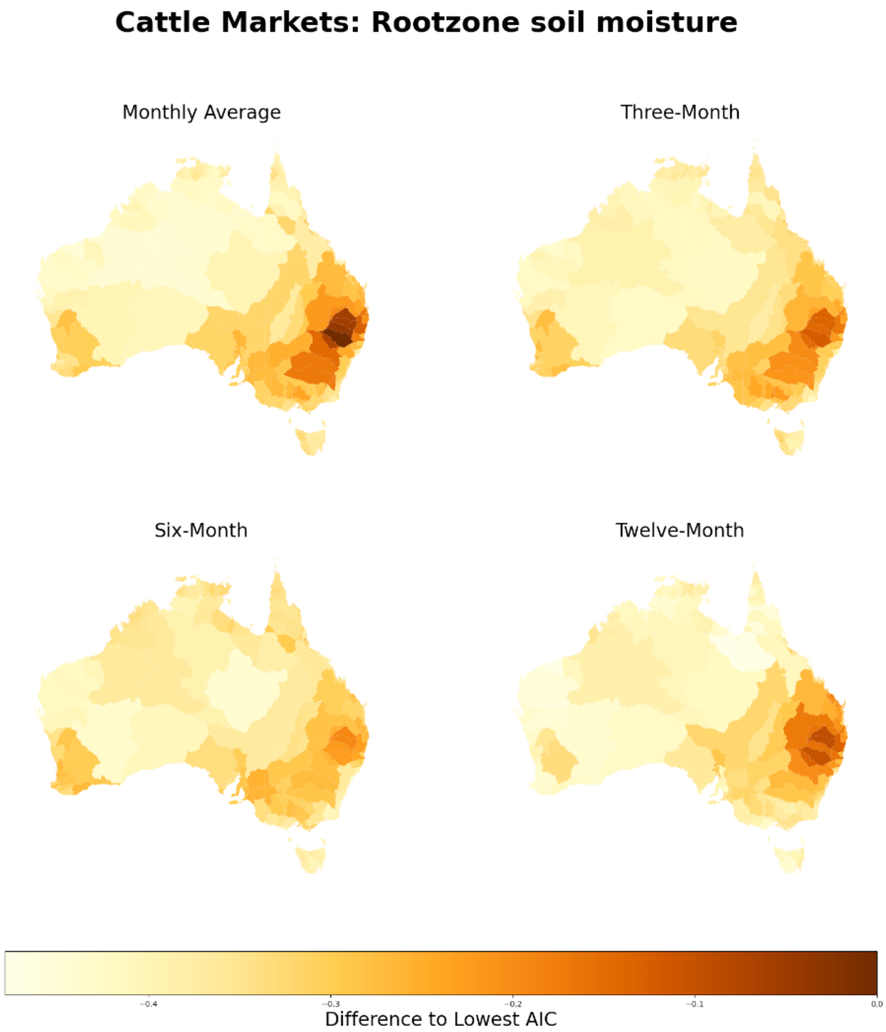
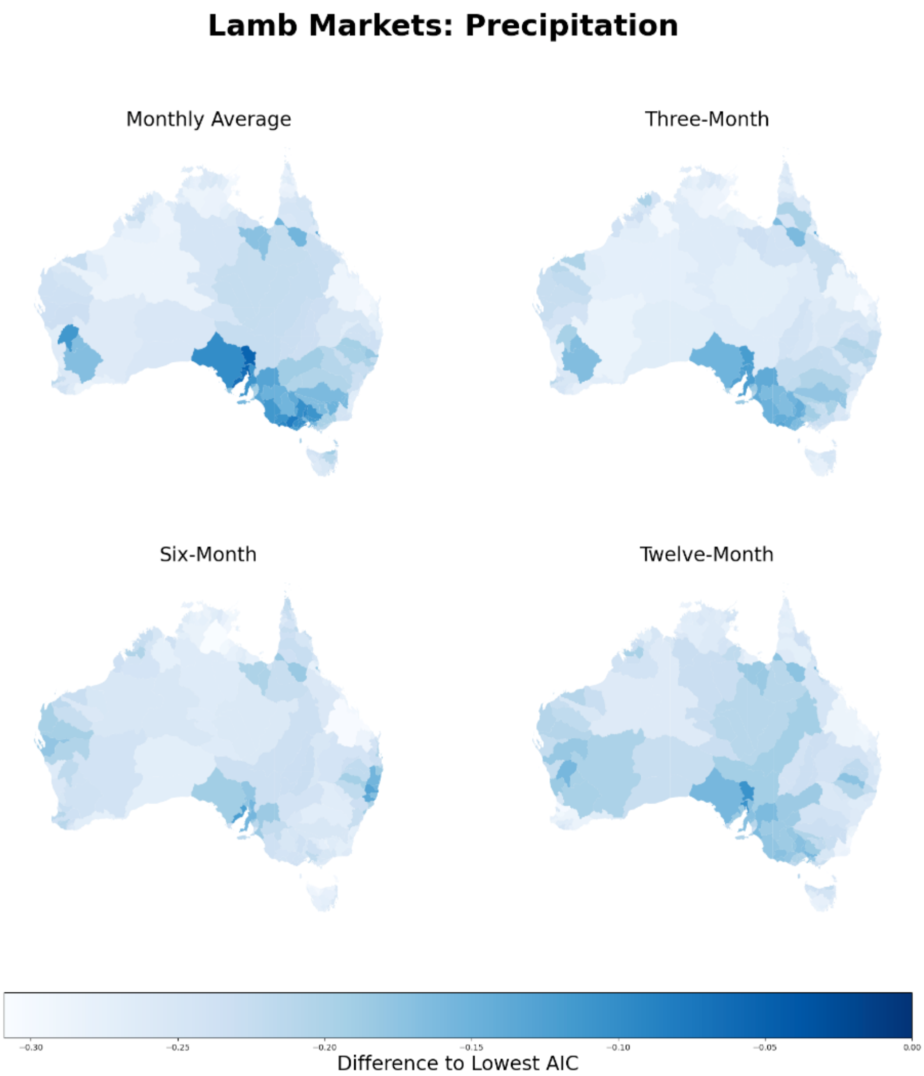


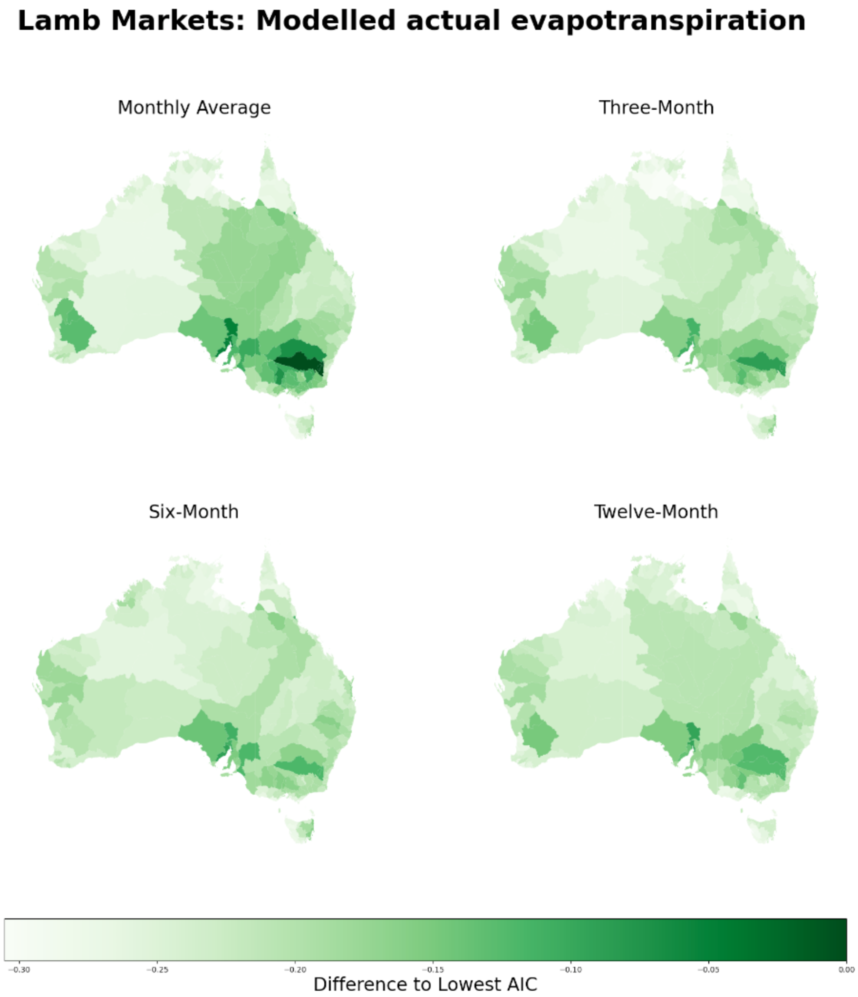
Figure 11 presents the AIC results for precipitation in explaining lamb markets. The shading of the figure indicates that the strongest locations for explaining lamb markets are regions in southern NSW, VIC, and southern SA. The figure also highlights the strength of monthly average precipitation in explaining cattle markets, as opposed to longer time aggregations. The dark shading in Figure 11 aligns similarly to the lamb density visualization in Figure 8.

Figure 11. Strength of Precipitation and Region for Explaining Lamb Markets



The strongest weather measurement and river region was the monthly average modelled actual evapotranspiration in the Murrumbidgee River region within the Murray-Darling Basin in southern NSW, as displayed in Figure 12. This region is one of the geographically larger regions in the southern Murray-Darling Basin and is located near regions with high lamb population densities.

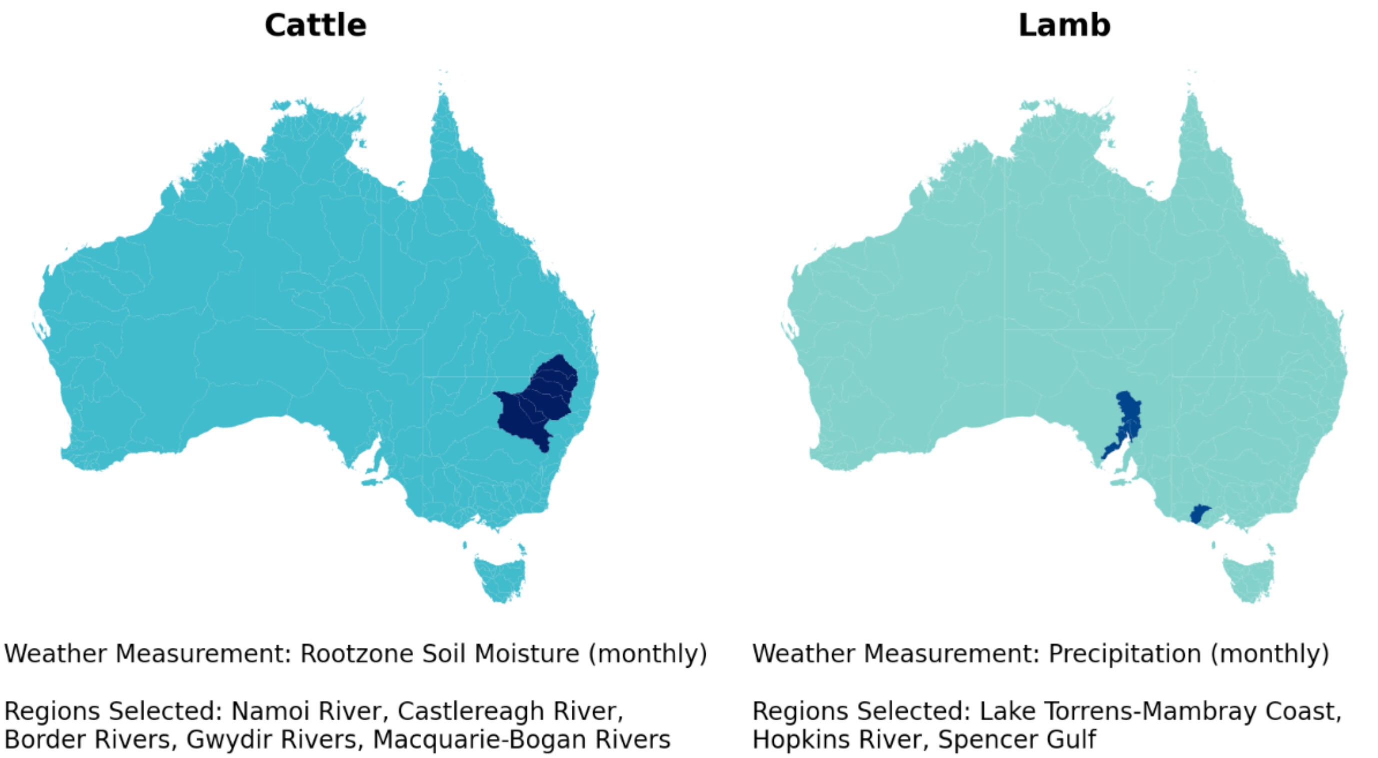
Figure 12. Strength of Evapotranspiration and Region for Explaining Lamb Markets



Remember that these results only examine the explanatory power of a single location and weather measurement for each market. In reality, we must conceptually recognize that all of these locations simultaneously affect markets. However, including all of them would complicate our statistical models by making it difficult to define causal relationships and increase the risk of overfitting our results (i.e. making our results less stable). That said, because of the high correlation of weather across regions, by including one variable and location, we indirectly include all of the other locations that correlate with it. Consider for the cattle results, by including, say, just the Namoi River region soil moisture, we are also including all other regions that are similarly shaded dark above, as it correlates with the entire state of NSW at a correlation statistic of 0.85, and twenty-four other regions by more than 0.5. Those regions span the coastline from southern NSW to northern QLD.

In addition to the models and results presented above, we allowed for the possibility of the inclusion of the combination of regions as a potential weather location and measurement. We combined regions through simple averaging. In doing so, we aggregated the regions that were found to be the most explanatory for cattle and lamb markets, these are presented in Figure 13. They have been separated into regions to support multiple aggregation perspectives. For cattle, the strongest regions were found within the Murry Darling River Basin (MDRB) region. For lamb, the results were split between southern MDRB, SA, and VIC. With the regions we allowed for the possibility to select just top 2 locations, top 3, and top 5, as well as for lamb the combination of the top two locations from MDRB and the SA-VIC area. This expanded the potential set of regions to include beyond just regions to slightly larger areas, but not so wide as to reflect state-level aggregation, which was found to be less explanatory.

Figure 13. Regions with Strongest Explanatory Power for Markets



For cattle, the simple monthly average root zone soil moisture (0-1m depth), % full across the Namoi river, Castlereagh River, Gwydir River, Macquarie-Bogan Rivers, and Border regions was found to be the strongest weather measurement (left: Figure 13). For lamb, the average precipitation across Lake Torrens-Mambray Coast, Hopkins River, and Spencer Gulf was the best explanatory location and measurement (right: Figure 13). These two aggregations are used to reflect weather in the results section of the report.

Curiously, the model selection process selected a contiguous group of regions for cattle and rootzone soil moisture, as opposed to precipitation and a non-contiguous collection of regions for explaining lamb markets. We speculate this difference in selection could be due to the fact for cattle production that occurs just off the eastern shoreline, there might be more abundant rainfall but the key for changing decisions is how much of it is retained in soil. For lamb, which observes greater production concentration in more southern, and drier areas, precipitation was the more important variable. Further, because rainfall tends to be more indicative than soil moisture, the greater geographical disaggregation may help reduce the noise in precipitation data for any one region.

While our main findings are presented with only the strongest location selected, we additionally evaluated the inclusion of multiple locations as explanatory variables, which is presented in appendix 14.2. To do so, we re-estimated the model across all the weather variables while including the strongest, previously mentioned, location. The inclusion of multiple weather variables marginally increased how much explainability of market volatility could be attributed to weather. Suggesting that more variables could increase what is attributable to weather, the singular variable was comparatively much more effective.

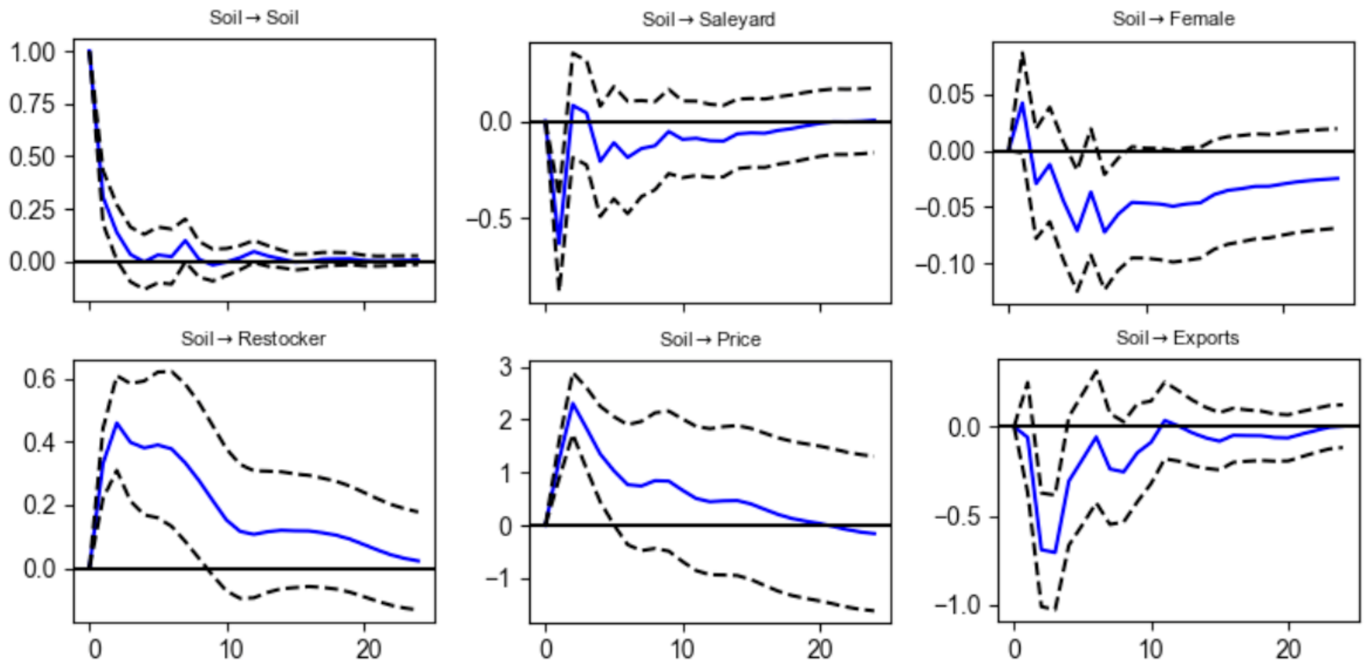
9. Results

Econometric results are shown for both the cattle and lamb markets below. Results are presented in two formats: impulse response functions (IRF) and forecast error variance decomposition (FEVD). An IRF measures how a one-time shock to one variable affects other variables in the system over time. This helps in understanding the dynamic relationships between variables when there are many variables to consider simultaneously. The IRF results show how a one-time increase in soil moisture impacts each variable for twenty-four months. The FEVD quantifies how much of the unexplained variation in a variable—over different time horizons—is caused by shocks to itself or other variables in the system.

Notably, weather was treated as an endogenous variable for estimating the IRF and FEVD, despite a clear understanding it is not impacted by the other market variables. This decision is because VAR frameworks are designed only to analyse interactions among endogenous variables. Accordingly, while we could estimate IRF and FEVD for all the other variables if we were to treat weather exogenously, we would be unable to recover the estimated weather impacts. Our results do not change meaningfully whether we treat weather as endogenous or exogenous. This is because, intuitively, no statistical relationship was shown between the other variables to cause weather. A comparison of the IRFs are presented in Appendix 15.1 with weather treated exogenously and endogenously.

9.1. Cattle Market Results

Figure 14. Increase in Soil Moisture Reduces Cattle Supply and Increases Price



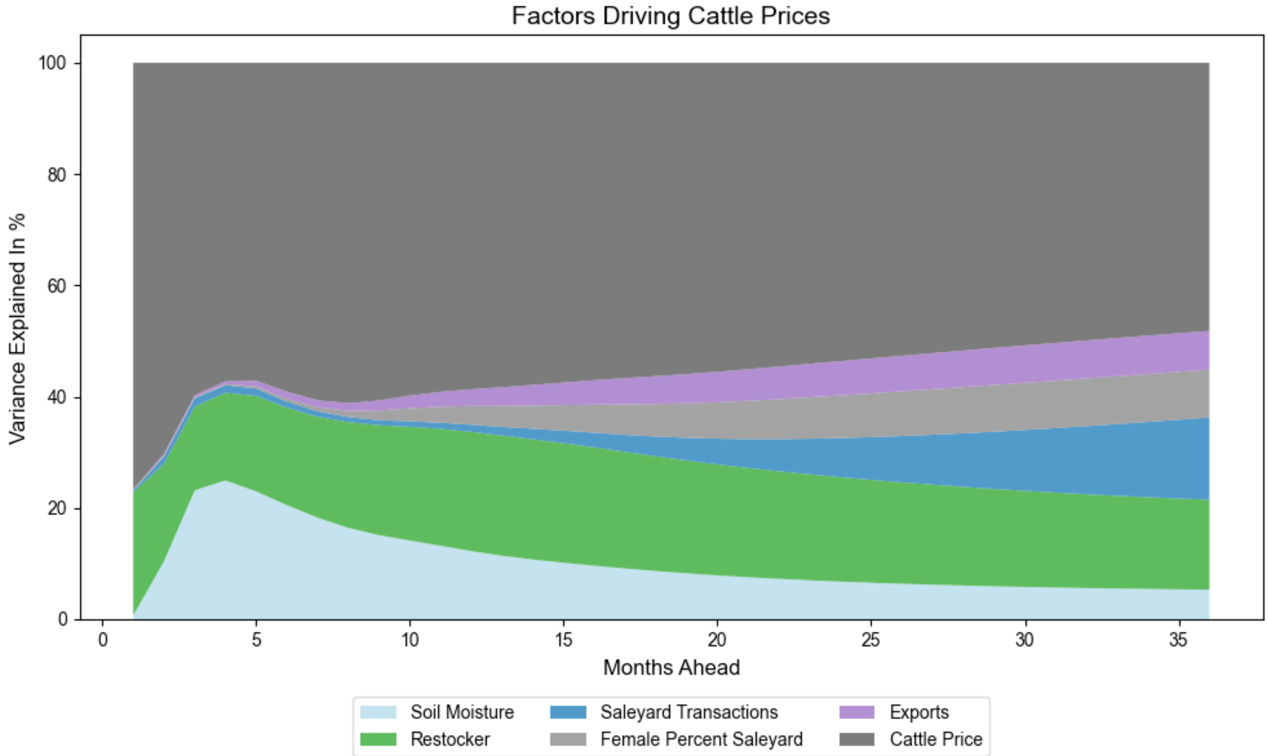
Notes: Figure is the IRF for cattle markets, looking just at the responses to a 1 percent change in soil moisture. Saleyard refers to the monthly cattle transactions, Female is the percentage of saleyard transactions to heifers, Restocker is the spread of restocker saleyard steer price to market steer price, price is the monthly average steer saleyard price, and Exports is the monthly beef and veal export volume. X-axis is months after initial shock. Y-axis units are from top-left to right and down: %, 1,000, %, c/kg lwt, c/kg lwt, and million kg.

Figure 14 focuses on the results related to weather, illustrating how a one percent rise in the monthly average soil moisture percentage from Namoi, Castlereagh, Gwydir, Macquarie-Bogan, and Border regions in just one month impacts all other variables over the next twenty-four months. The sub-labels in each figure indicate the causal effect of soil -> to another variable, while the blue line is the estimated effect and the black dotted lines are the 95% confidence intervals.

The IRF figures reveal that an increase in soil moisture initially leads to a decrease in saleyard transactions (Fig 8: top-center), an increase in restocker price spread (Fig 8: bottom-left), a rise in cattle prices (Fig 8: bottom-center), and a decline in export volumes (Fig 8: bottom-right). The proportion of saleyard transactions involving heifers shows a negative correlation with higher soil moisture (Fig 8: top-right), although it takes approximately ten months for this effect to statistically diverge from zero. The results suggest that for every 1% increase in soil moisture in just one month, the steer prices increase by 2 c/kg. These findings align with the supply shock theory, which suggests that a decline in supply in the short-run increases prices. Notably, the most enduring effects of changes in soil moisture are on the restocker price spread and the percentage of females. This outcome mirrors our expectations that weather significantly influences producers' decision-making over extended periods, especially regarding grass-fed and pasture conditions. The comprehensive IRF chart encompassing all shocks and variables is available in the appendix (Figure 21).

Figure 15 illustrates the FEVD for the cattle market. The shading in the FEVD chart indicates how much of the variability of the series presented is explained by the other variables, hence why the y-axis ranges from zero to one-hundred. Note, a common feature of any FEVD result is that it is more likely to overestimate the effect of the series itself in driving the price variability, as it effectively behaves as a catch-all for all factors the other variables in the model can not explain (e.g. trade disruptions, biosecurity issues, changes in costs of inputs, etc.). As explained by processors consulted during preliminary steps of this research, this variable also likely includes reactive momentum behaviour of producers reacting to low prices by increasing sales to avoid “being the last one to sell” in a down market, or vise-versa when prices are rising.

Figure 15. Cattle Price Variability Driven by Soil Moisture and Restocker Demand in the Short-Run



The FEVD for the cattle market indicates that price variability in the short term is mainly influenced by the latest price (grey), soil moisture (light blue), and restocker spread (green). In the first six months, more than 40% of cattle price variability stems from the interplay between the restocker spread and soil moisture. 25% of the price variability is due to soil moisture alone. Given the significant impact of soil moisture on restocker spreads, as demonstrated in Figure 15, it underscores the crucial role of weather in short-term price fluctuations. Abundant or low soil moisture significantly affects animal supply. While discussions often focus on how drought influences decisions, these results also emphasize how favourable grazing conditions impact market trends because it alters the incentives of restockers.

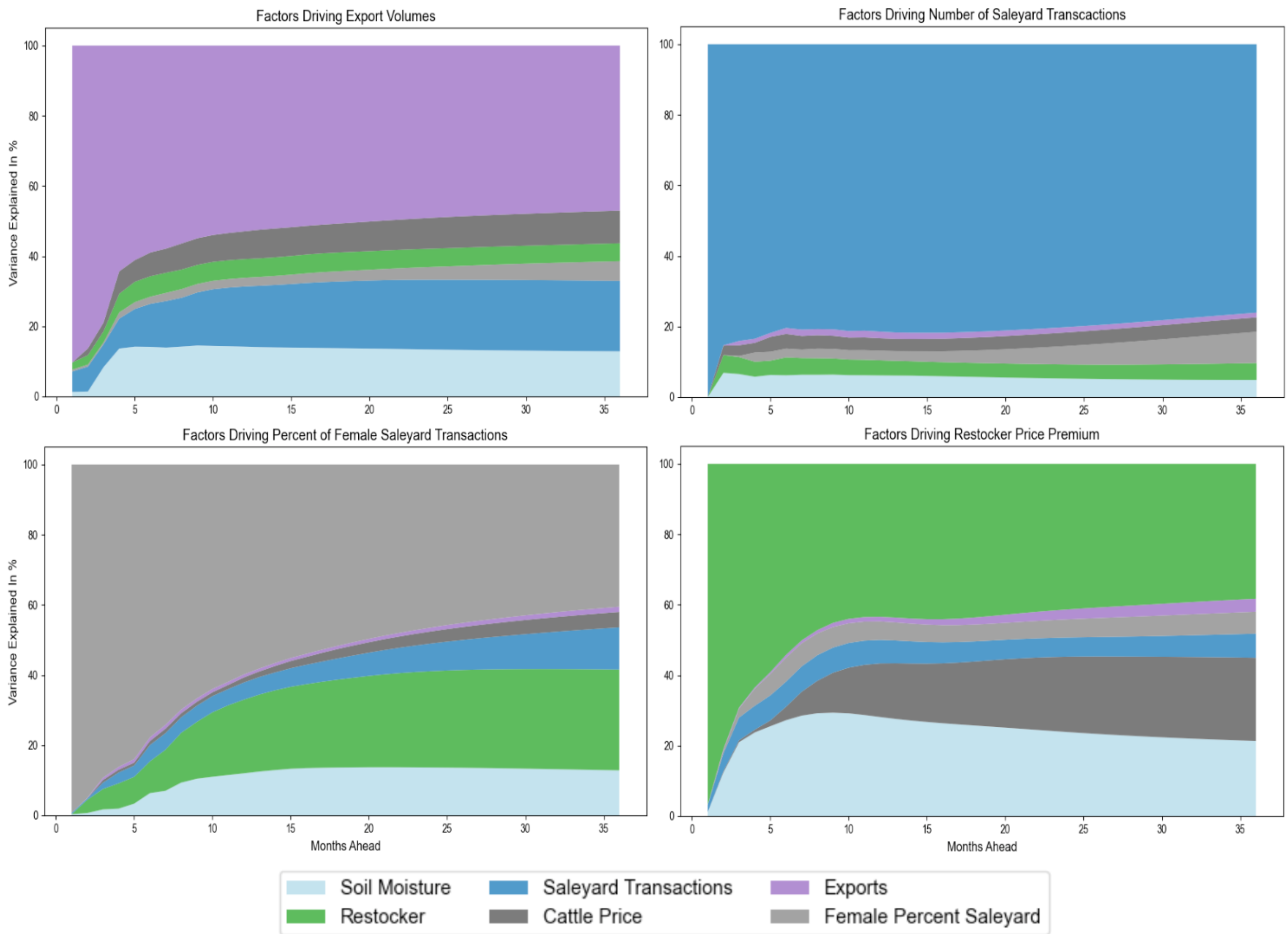
In the medium- to long-run, the direct impact of soil moisture on price variability transitions to a role of restocker spread in driving price variability, as well as the number of cattle transactions and female percentages. The results follow intuition in that weather immediately impacts the price and the supply of restockers, which accordingly impact the long-run features of the market being cattle numbers and breeding herd size. This transition of price explainability from soil moisture to supply and demand variables highlights the direct and indirect role of weather on markets. The chart explains and shows the direct effects of weather. Still, those weather effects can also impact the other variables, such as female percent, over longer horizons, which then impact price.

Soil moisture meaningfully influences short-run price variability (25%), more so than supply (1%), emphasizing how processing constraints affect price determinants in the short-run. Intuitively, one might assume soil moisture impacts prices directly by altering supply, but the supply and demand charts (Figure 5) reveal that an increase in supply (a rightward shift) doesn't change the measurable quantities supplied due to short-run processing limitations. Thus, the short-run effect of weather on prices partly results from processing constraints occurring during poor pasture conditions and the inelasticity of demand when pasture conditions improve, which is further supported by the magnitude of the effect of the restocker spread on price.

Although weather has a lesser direct impact in the long term (moving from 25% to 5%), it still influences other supply factors significantly in the short-term, which are anticipated to drive long-run impacts. For example, a reduction in soil moisture will directly impact price (as discussed), but it also impacts breeding herd and transaction count in the long-run, which then directly contribute to price variability. Transaction count, which does not meaningfully contribute to initial price variability, is the second largest factor (15%) thirty-six months out aside from price (48%) for explaining long-term cattle price variability. Restocker spread is consistently a strong contributor to explaining price variability (16% thirty-six months out), likely due that sector of production the most flexible in changing production choices.

A considerable portion of price variability can be attributed to demand factors, which would be captured by price and exports in the graph above. Importantly, how much price variability is attributed to price itself is also likely due to measurement errors in the other variabilities (Gorodnichenko and Lee, 2020), meaning the shaded region in Figure 15 for cattle price is likely to also serve as a catch-all for all that can not be explained. In time-series modelling, the latest observation is most often the strongest predictor of future trends, thus will “explain” a large portion of the variability for any given variable. This means that the series being measured is likely to be the largest contributor to explaining its own variability. Accordingly, while the FEVD results above attribute a large share of price variability to price, soil moisture and restocker spread substantially affect price variability in the short term. Figure 16 displays the FEVD results for the other endogenous variables in the cattle model.

Figure 16. FEVD Results Show Weather Factors Heavily in Restocker Spread and Breeding Decisions

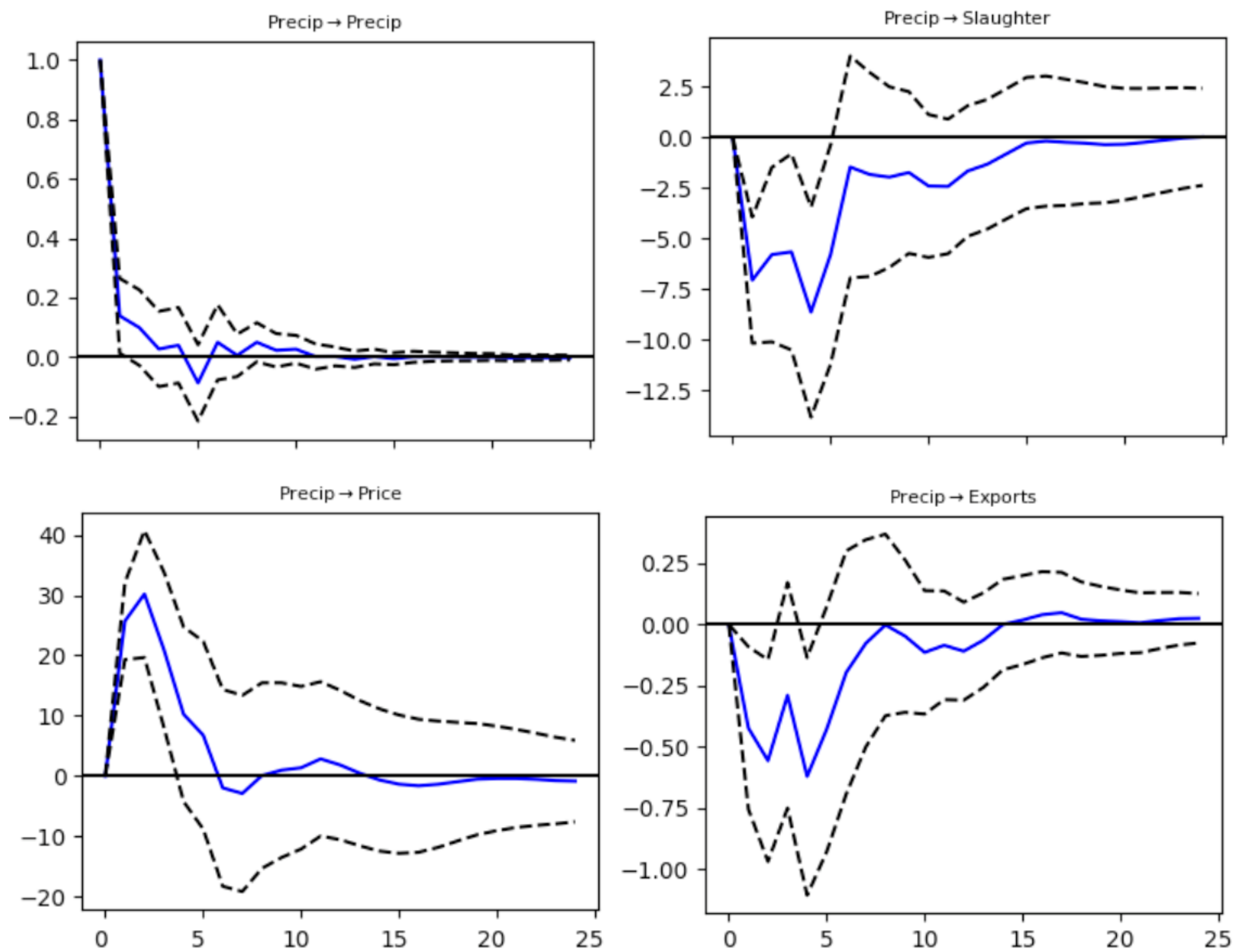


The variability of export volumes (Figure 16: top-left) is most explained by its own historical volumes (~80% in the short-run and 47% in the long-run), followed by saleyard transactions and weather. This result is expected because the logistics required and long-term contracting in export trade often cause trade flows to be more sticky than other variables. Saleyard transaction variability (Figure 16: top-right) is primarily explained by historical transaction numbers (76% in the long-run). This result is likely explainable by the variability of the measurement and how changes in levels month to month do not appear to correlate with any other factors. This is partially visible in Figure 6 in the prior section, where reported transaction counts can vary considerably from month to month, but the other variables are far less variable. The next largest contributor to explaining saleyard transaction counts is the percentage of transactions being heifers, which follows logic that long-run supply numbers relate to the breeding herd today. Aside from itself, the percent female saleyard transaction (Figure 16: bottom-left) is impacted by weather (10-14%) and restocker spread (up to 29%). These variables theoretically should be correlated with breeding herd decisions as they relate to feed availability, as well as the price farmers are likely to receive for their breeding animals for slaughter. Restocker spread (Figure 16: bottom-right) is explained mostly by itself, weather (up to 29%), and cattle price (24%). These results highlight both the direct way in which weather contributes to market variability, as well as the indirect way through breeding conditions and restocker grass-fed spreads. Appendix 15.2 presents results of different model specifications to test the sensitivity to dropping variables, as well as adding more weather variables. These results in the appendix are consistent with those presented here.

9.2. Lamb Market Results

Figure 17 presents the IRF results for the dynamic impact of an increase in precipitation on lamb markets. Precipitation is measured by the monthly average of daily precipitation in Lake Torrens-Mambray Coast, Hopkins River, and Spencer Gulf, as this location was found to be the most explanatory weather measurement and location for driving lamb markets. The directionality of the impacts of weather in lamb markets mirror those found by in the cattle results. An increase in precipitation of one mm reduces slaughter count (Figure 17: top-right), raises prices (Figure 17: bottom-left), and reduces export volumes (Figure 17: bottom-right). The persistence of the shock on markets is less in lamb markets, as the results suggest a short time to revert to trends. This result follows the expectation of a shorter response in markets to shocks because of the quick biological response of lamb relative to cattle as well as the intensity of grazing of lamb allowing for more variable responses to shocks.

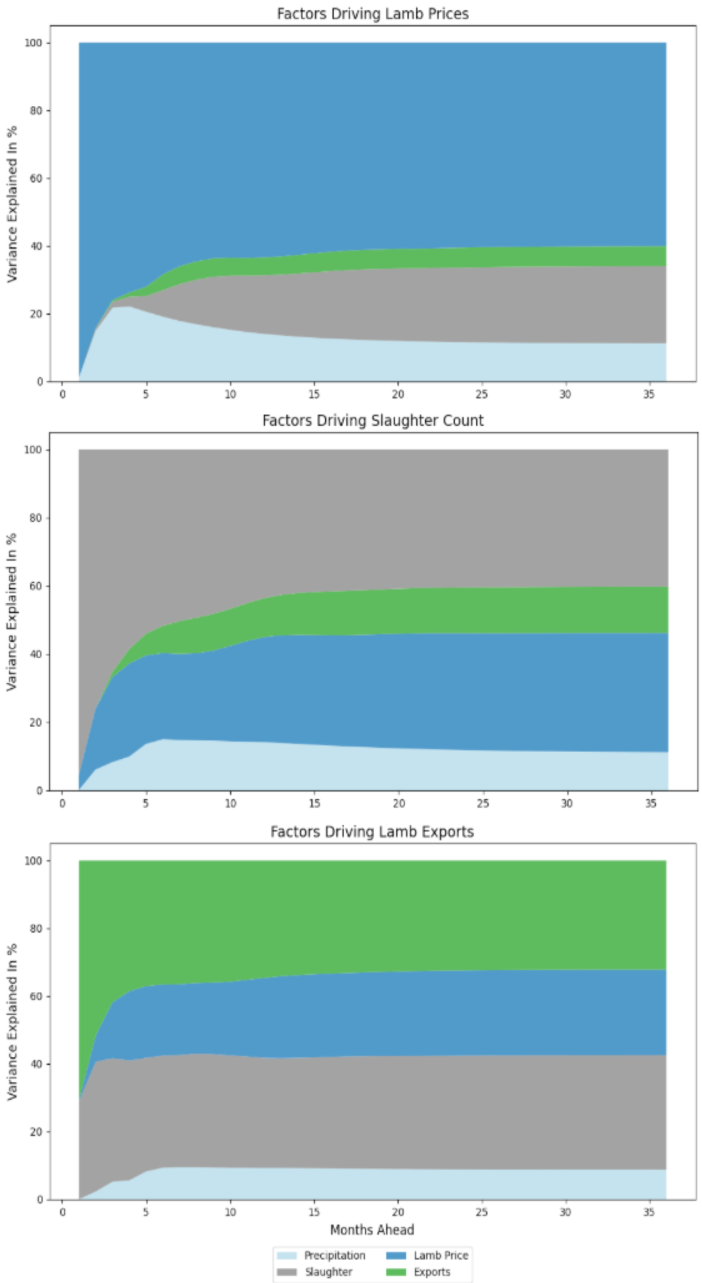
Figure 17. Precipitation Reduces Lamb Slaughter and Increases Prices



Notes: Figure is the IRF for lamb markets, looking just at the responses to a 1 percent change in precipitation. Slaughter refers to the monthly lamb slaughter, Price is the lamb price, and Exports is the monthly lamb export volume. X-axis is months after initial shock. Y-axis units are from top-left to right and down: mm, 1,000, c/kg cwt, and million kg.

Figure 18 presents how much of the variability of lamb markets is attributable to each variable. Roughly 22% of the lamb price variability (Figure 18: top) is driven by precipitation in the short run. As the horizon extends, lamb price variability is increasingly explained by slaughter count (up to 23%). Lamb prices were found to be significant drivers of the variability of lamb supply (Figure 18: centre) in a way that was not as evident in the cattle market. This increased role is likely attributable to lamb producers being more responsive to prices than cattle producers. Export volume variability (Figure 18: bottom) is highlighted as being influenced by slaughter count and prices, highlighting the role of production volumes in driving exports, as well as the competitive global export market for price.

Figure 18. Lamb Markets Driven by Price and Weather

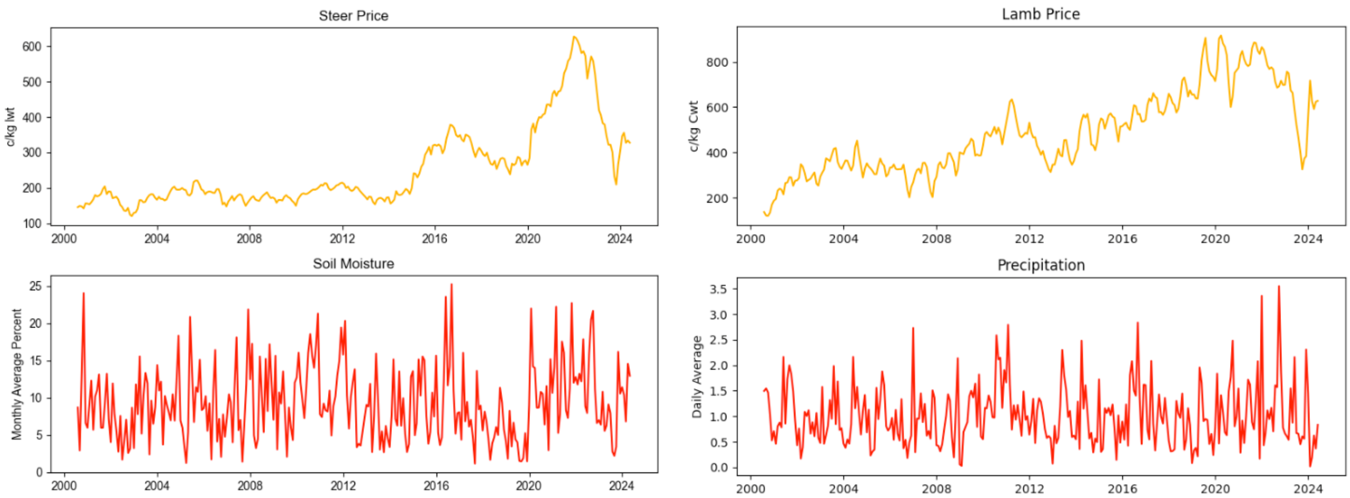


10. Discussion

The prior section presented the results of the impact of weather on cattle and lamb markets. While at first blush, only attributing 20-25% of cattle and lamb price variability to weather suggests a limited impact, but in comparison to all other variables included, it was often the largest contributor to the variability of the market variables. These results also highlight how to consider what we think of as weather beyond dichotomous drought or no drought dialogue, as well as that presented in the cattle cycle literature.

Figure 19 presents the price of steer and lambs and each weather variable used in the prior section. While the discerning eye can find the prolonged periods of good or bad soil moisture or precipitation in that chart below, one can also see that each variable is volatile. This is because while prolonged patterns of good or bad weather can shock livestock markets, at the same time it is continuously affecting markets both regionally and nationally in ways that can not always be readily observed or explained. The results here have shown with a continuous treatment of weather-related variables, how even small month to month changes in weather can drive changes in markets that would otherwise not be reflected by simplified dichotomous market herd rebuilding discussions. They have also further highlighted how weather not only impacts production decisions during times of drought, but also how good weather can also drive prices higher because grass-fed production becomes increasingly competitive. This complexity is often overlooked when presented in generalized discussions.

Figure 19. Prices and Weather[6]



For example, consider the relationship between soil moisture and cattle price from 2018 to 2024, as shown in the figure above (top-left & bottom-left). As soil moisture declined into 2020 cattle prices declined. When soil moisture increased in 2020, prices also increased. The results highlight that the increase in price for cattle was due in one part to a reduction in female cows and lower cattle transactions since supply was impacted by early drought-related conditions. But soil moisture improvement and restocker demand were significant contributors to the run-up in cattle prices from 2020 to 2023. These results highlight the role of grass-fed production and herd decisions, which are directly impacted by weather, as important components of the supply-demand relationship driving markets and prices.

[6] Soil moisture percent is the average rootzone soil moisture (0-1m depth), % full simple average across Namoi River, Castlereagh River, Gwydir River, Macquarie-Bogan Rivers, and Border regions. Precipitation is the monthly average precipitation across the Lake Torrens-Mambray Coast, Hopkins River, and Spencer Gulf. Weather data is from the BOM AWO. Prices are saleyard transaction prices for yearling steers and lambs in QLD, VIC, SA, and NSW, as reported by Meat and Livestock Australia (MLA).

10.1. Monitoring Weather Variables and Locations

Although the idea of weather affecting markets is straightforward, quantifying its impact for statistical or practical discussion is quite complex. Weather, as commonly understood, encompasses various elements, including temperature, soil moisture, and soil conditions. Even within that broad set of measurements, statistical analysis requires aggregation of these variables over time frames (minutes, hours, days, weeks, months, etc.) and geographical areas (such as rain gauges, fields, farms, regions, and states). Accordingly, evaluating all possible time, location, and measurement choices presents statistical challenges regarding what to include.

The research here estimated the impact of weather on cattle and lamb markets using a variable selection process that iterated through many weather variables, measurements, and locations to find the measurement that best explained changes in cattle and lamb markets. The results found that the soil moisture variable for the regions located across the south QLD and north NSW borders was the most explanatory area and measurement for cattle markets.

Additionally, while one region and weather measurement might seem illogical for explaining all of the ways weather impact the cattle market, the results in the appendix highlight how adding additional variables does not meaningfully increase the explanatory power of weather in markets. This is because while one region measures only itself, it naturally correlates strongly with other variables and locations. The correlation of weather across regions means you can use fewer variables to measure weather while still indirectly incorporating weather's impacts in other areas. This effect can partially be seen in the high correlations shown by neighbouring locations in Figure 10.The best regions for explaining lamb markets were in South Australia and Victoria regions. Unlike the cattle results, the optimal combination of regions was not geographically contiguous. The combination of non-contiguous regions highlights the value in aggregating multiple regions to balance out the individual region level noise to better measure its broader impacts, as well as how precipitation in this combined region correlates with all neighbouring areas, as can be seen in Figure 11.

Notable in the results was how the power of the weather variables differed, either in precipitation, soil moisture, or evapotranspiration, depending on the market or aggregations (time and location). For cattle markets, soil moisture was the strongest variable at the river region level and at the combined five river-region level. For lamb markets, however, individually, evapotranspiration was the most explanatory variable for evaluating just one river region, but when further aggregation was considered, precipitation was found to be a more explanatory measurement. This is likely partly due to the high correlation across these measurements, but potentially as well meaningful to how weather impacts production differently in southern Queensland and northern New South Wales versus Victoria. Those regions along the Eastern coast observe higher levels of rainfall, and thus, it might be more important to track changes in how much the soil is retaining for monitoring conditions. In the drier southern regions, such as the South Australia Gulf or western Victoria, precipitation is the most important variable for tracking lamb markets.

10.2. Policy Implications

Given the price variability, it's reasonable to question how policy can enhance market welfare and mitigate price fluctuations. However, as demonstrated by the findings here, weather-related factors are the primary driver of price variability in the short to medium term. Meaning, according to the price stability research summarized by Gouel (2012), the options for policies to stabilize prices without negatively impacting market welfare are limited. This is largely because price stabilization policies often end up transferring the welfare from producers to consumers or vice versa (Gouel and Jean, 2015), as opposed to improving the welfare of the entire market. Stabilizing prices would likely require stabilizing supply, which, as shown by the results here would have negative impacts on the market. Implementing supply controls for price stabilization will likely significantly reduce incentives for livestock producers to raise animals, especially since they benefit from market gains when soil moisture levels improve. Additionally, restricting the sale of animals to maintain elevated prices during drought could prove detrimental to pasture conditions and livestock health, as this might incentivize producers to keep animals in conditions with lower feed availability or increase the degradation of soil conditions.

The price stabilization literature underscores the role of policy in enhancing market welfare through the dissemination of information regarding current and expected supply (Gouel, 2012). Aside from any cyclicality in weather causing a livestock cycle, another potential reason for observing price cyclicality would be due to naïve producers building herd sizes to levels that the market can not bear, then retreating quickly when prices fall. This cobweb theory of market goes that when current period prices are high, producers will increase supply to capture the perceived expected future profits, not recognizing all of their neighbours doing the same (Nerlove, 1958). Because of the delay in the decision from breeding to animal sales, by the time the market has realized all of the new animals, prices fall again. While producers are likely not fully naïve in recognizing how their decisions relate with broader market trends and future prices, cyclicality in markets has been observed (Heilbron et al., 2025). Thus, to minimize this market welfare-reducing behaviour, policymakers should aim to produce information to inform producers of the current and anticipated supply of animals to markets, and importantly, what that supply would mean for future prices. This way, producers can make better informed decisions about their marginal production costs and anticipated revenues.

It is important to recognize that while the supply-demand charts highlight the role of processing constraints on the entire market, this oversimplification can also imprecisely reflect the role of regional markets in driving outcomes, as highlighted in research (Morales et al., 2017). If a region observes an increase in supply beyond the processing capacity of that region, it is likely to drive prices everywhere lower. Therefore, targeting policies that reduce processing constraints, even just regionally, are likely to benefit producer and processors during times of increased supply: These supply constraints may include:

- Insufficient access to labour, and/or inflexible employment terms
- Limited supply of suitable housing for employees
- Supply chain logistics including roads and ports
- Access to energy, materials and other inputs
- Regulatory costs and market access
- Constraints on plant expansion, mergers, and acquisitions

The regionality of market outcomes and how they translate nationally also highlights the role of competition amongst processors regionally, as well as nationally. Changes in weather alter the marginal costs of producers, which leads to changes in supply, both in terms of increasing supply when drought hits or decreasing supply when pasture conditions are abundant. Competition is primarily driven by the availability of processing capacity in the short run (MacDonald et al., 2023; Paul, 2001). When capacity is high relative to supply it increases the competition for animals and firms compete to lower marginal processing costs so they can pay more to bid animals from other firms. The scale economies and limits of processing capacity in the short run create competition in ways that are not captured by competition metrics that just measure the number of firms or firm size (MacDonald, 2024). Accordingly, policies which seek to maintain or increase processing capacity are likely to foster greater competition, even if it does not change the number of firms within an industry.

10.3. Study Limitations

Every study comes with limitations regarding the research questions it can adequately address. This research sought to assess the influence of weather on cattle and lamb markets throughout the Eastern states of Australia. Given the extensive range of production areas and the variability of weather conditions, this wider focus presents some constraints to statistical modeling. Agricultural production is primarily a local decision that contributes to broader macroeconomic markets, making it challenging to pinpoint how local weather influences the entire market. Consequently, we suspect that the findings regarding the extent of weather's impact on markets may underestimate the full effects due to aggregation in the measurements. Additionally, it does not account for localized market phenomena that can influence local markets and potentially have wider repercussions. For instance, a tropical storm in major production or export areas is certain to affect markets in ways that our study has not captured. Conversely, a flood that makes an important transportation route insurmountable would impact markets but would not be captured with the approach presented here.

Furthermore, because we had a limited number of observations, our methods could not evaluate any non-linear effects of weather, like when excessive soil moisture negatively impacts production. For example, perhaps when soil moisture decreases up to a threshold, production decreases minimally, but beyond this threshold it can decrease markedly. Although this represents a limitation, the results indicate that such occurrences may be less common than the data implies.

Additionally, a key challenge in linking price variability over time—one of the principal research questions of this report—to specific variables lies in the natural volatility of any time-series data and the adequacy of the variables used to account for this variability. The findings revealed a strong influence from several variables (such as supply, exports, restocker spread, weather, etc.), yet they do not completely encompass all the elements affecting price variability over time. Consequently, the challenge of omitted variables in econometric time-series analysis will heighten the degree to which price variability can be attributed to its own fluctuations. Even with this challenge in cattle markets, the models were able to attribute 59% of long-term price variability to the variables considered in this analysis

A key factor anticipated to drive price variability is supply, particularly from saleyard transactions or slaughter. However, measuring supply is fraught with statistical noise. For example, in December and January, supply numbers can diminish drastically. Market participants recognize this pattern, aiding in price stabilization. Still, statistical methods struggle to accurately capture this difference between actual and expected supply, which may sway outcomes as much, if not more, than actual figures. Although techniques were applied to address this seasonality to improve model performance, the inherent volatility will limit the extent to which price variability can be attributed to supply changes.

11. Conclusions

This report measures how weather influences prices of cattle and lamb over time. Both theoretical and econometric findings emphasize how weather affects animal prices directly by altering producers' supply and highlighting processing constraints that shape outcomes. When adverse weather increases short-term supply due to limited feed, it can overflow the processing capacity, leading to lower prices. The results show a reduction in soil moisture of 1% in just one month can reduce steer prices by 2 c/kg. Conversely, improved weather allows producers to raise animals at reduced marginal costs, resulting in price increases as processors compete by raising bids for livestock. A persistent six-month increase in soil moisture by 5% was estimated to increase saleyard steer prices by around 60 c/kg.

This report finds that 40% of short-term variability in cattle prices is explained by fluctuations in restocker demand (15%) and weather conditions (25%). Over the long term, herd conditions become more significant in affecting price variability. While exports influence cattle prices (7%) over time, domestic supply factors (breeding heifers, herd size, and restocker demand) exert an even greater effect (45%).

In contrast, lamb price changes are also affected by weather in the short term (22%), but to a lesser extent than in cattle markets. Long-term lamb price variability is significantly influenced by domestic supply (23%) and exports (6%). Although weather accounts for 25% and 23%, of short-term price variability for cattle and lamb, respectively, which may seem lower than expected, this reflects only its direct measurable impact. Including restocker demand, which is closely tied to weather, raises the percentage of cattle price variability attributed to weather-related factors to 40% in the short run. Since fluctuations in cattle supply and export volumes contribute only slightly to short-term variability, the impact of weather and restocker demand is considerable (40%) in explaining cattle price changes.

Overall, this report finds that a substantial amount of price variation in the short and long run can be attributable to weather-related supply shocks. The susceptibility of these markets to weather and how that impacts decisions through changes in costs along the supply chain are important considerations for policymakers to understand, not just in terms of their direct impacts but also in terms of how they impact competition. The weather-induced changes to producers' production costs and how that relates to producer and processor incentives is critical to understanding market structure and competition. By better understanding how factors such as weather impact competition and costs, we can better tailor polices to improve the market welfare of all participants.

12. Recommendations

The findings of this study should be communicated to processors, producers, and policymakers with the aim of better understanding how livestock markets are influenced by weather and facilitating improved risk management. The findings in this study may be extended through exploration of the following areas:

- Additional analysis of weather impacts within regional areas, or for individual processors.
- Additional analysis of how markets for branded or premium cattle behave during dry/drought periods, as compared to non branded/premium cattle.
- Establishing models and tools that factor in weather indicators in key regions, combined with other explanatory indicators (restocker spread, saleyard transactions, female percentage slaughter etc.) to better estimate expected livestock supply and prices.
- Emerging opportunities to use new data sources (e.g. satellite feed base estimates), machine learning, advanced data analytics, and artificial intelligence (AI) to identify and model trends in livestock markets.
- Forecasting and monitoring the size of the herd to better inform markets of the anticipated future supply of animals, and its impact on price.
- Evaluating options to the feasibility and costs of policies that minimize negative externalities associated with processing constraints during periods of increased supply brought on by weather.

- Development of alternative methods to evaluate market competition beyond simplistic standard concentration indices that poorly explain how competition occurs in an industry with inelastic supply and demand that requires high initial investment costs but low marginal costs.

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14. Appendices

The appendix is separated into two different sections. Section 14.1 presents the full IRF results for cattle and lamb markets, treating weather as either exogenous or endogenous. The key takeaway in presenting these two sets of results is how the results do not meaningfully change despite this treatment of weather. Section 14.2 presents the results of alternative model specifications for the cattle and lamb markets. These models test the stability of the modelling results to specification choices related to endogenous variables to include and the inclusion of multiple weather variables. In the short-run, the results do not appear to meaningfully differ how much weather can be attribute to price variability. In the long-run, the more endogenous variables and the more weather variables included improve how much price variability is attributed to weather. That said, given these models' statistical properties, adding more weather variables will naturally increase what is attributable to weather; whether or not it is economically meaningful is in question. The results do not meaningfully change across the specifications, though more price variability is attributable to weather when more endogenous variables are included, highlighting the indirect impact of weather on the other variables.

14.1. Appendix 1: Sensitivity of Results to Endogenous Treatment of Weather

Figure 20. IRF of Cattle Markets with Weather Treated As Exogenous

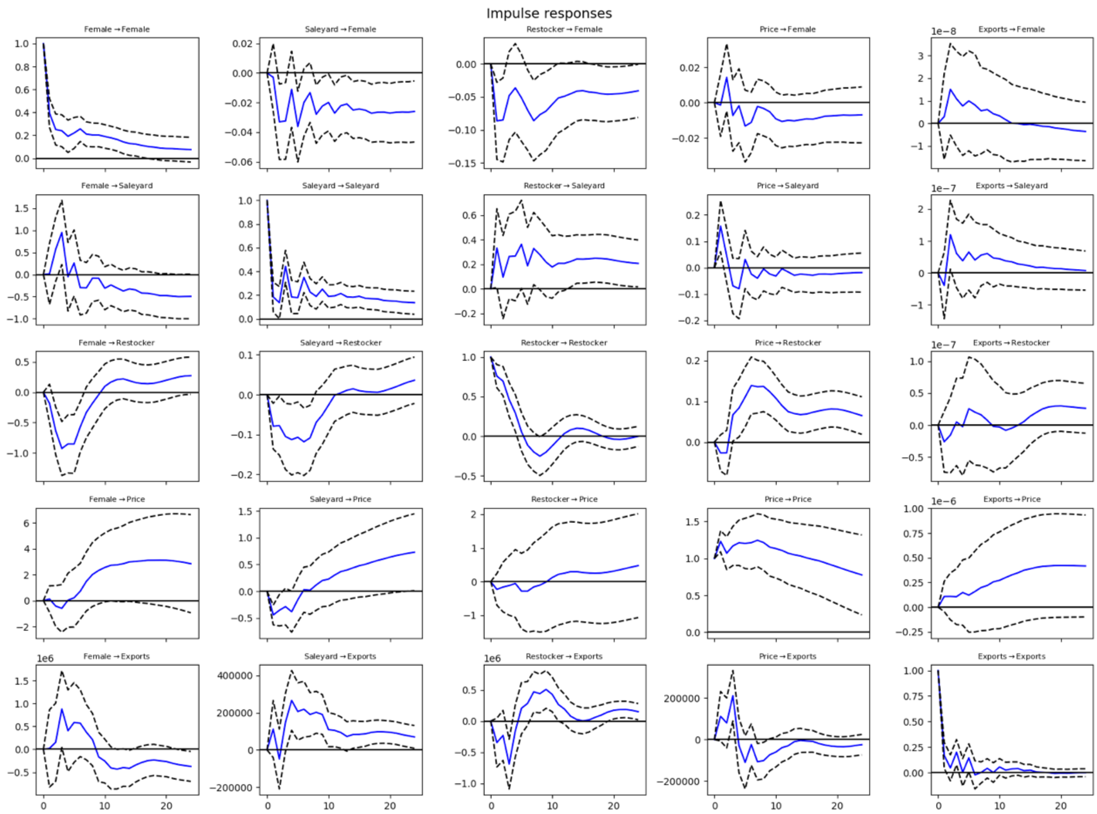
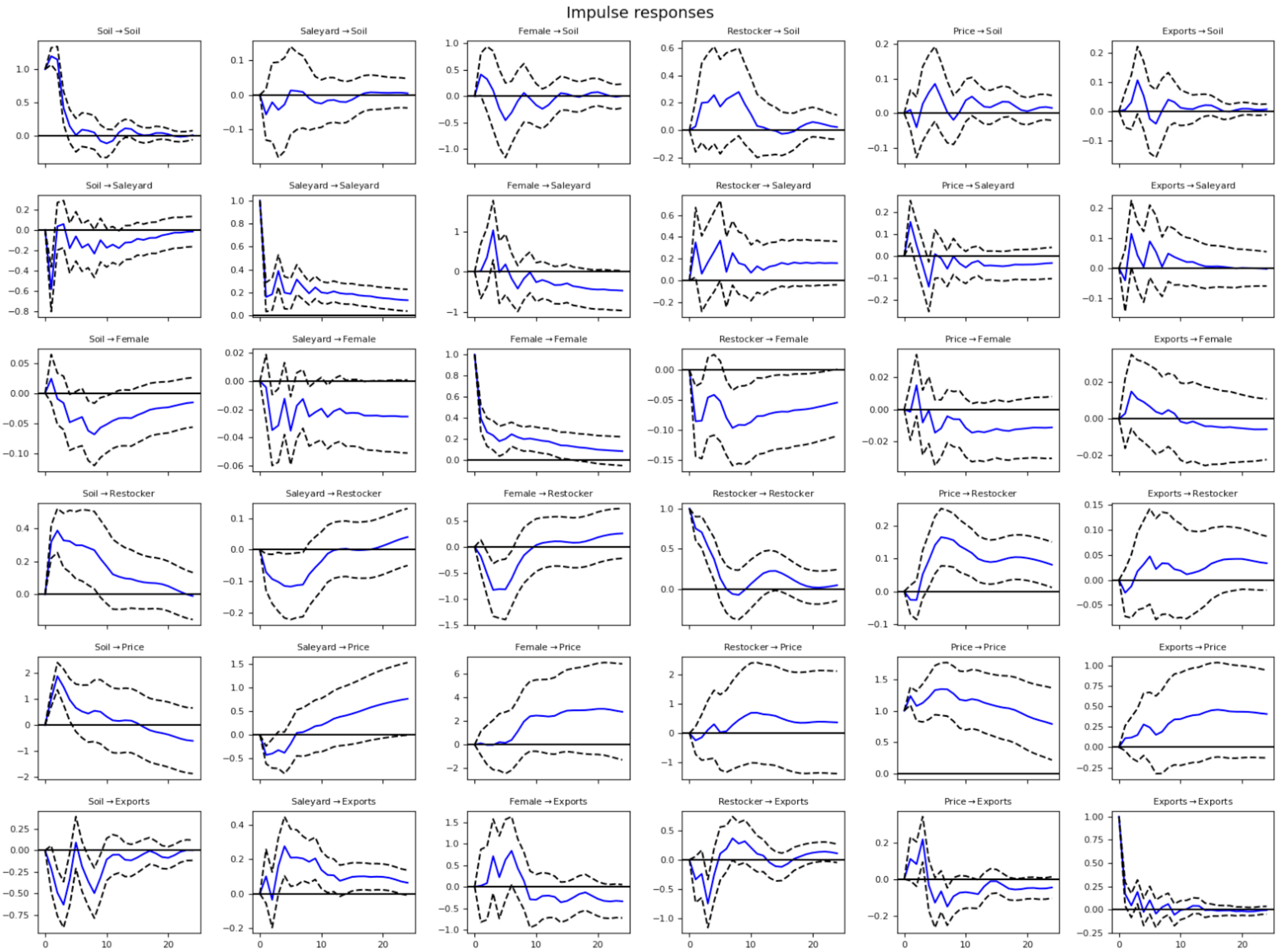


Figure 21. IRF of Cattle Markets with Weather Treated Endogenously



14.2. Appendix 2: Sensitivity of FEVD Model Results to Different Specifications

This appendix presents the FEVD results for the cattle and lamb models under differing VAR specifications to test sensitivity of the results for price variability that can be attributable to weather variables. The restricted models use the same variables as the main results presented in the paper but restrict the variables to only price and transactions (for lamb - slaughter). The "Full Model" presents the same charts but uses a second weather variable in addition to the main results. This model is to assess how adding additional weather variables impact how much price variability can be attributed to weather. The results from these different set of variables show a stability to the estimated impacts of those presented in the main part of the report. For cattle, 23.0% and 25.4% of price variability three months ahead can be attributed to precipitation for the restricted and full model results, respectively. At sixty months ahead, 4.8% and 11.9% of cattle price variability is attributable to precipitation for the restricted (Figure 22) and full models (Figure 23).

Relative to the main cattle prices results (3-months: 24.9%, 60-months: 4.4%), these additional model results show a similar estimated impact of weather on prices, but the greatest difference is in the longer horizons. The main results attribute more of the price variability to the other endogenous variables as opposed to when the second weather variable is included. This difference is likely not statistically meaningful given the large uncertainty when looking that far into the future. The limited impact to how much price variability is attributed to weather with the inclusion of the second weather variable is likely attributable to the high correlation of weather across locations, as the inclusion of one weather variable is likely capturing much of the response.

Figure 22. Restricted Cattle Model: Estimated Soil Moisture Impacts

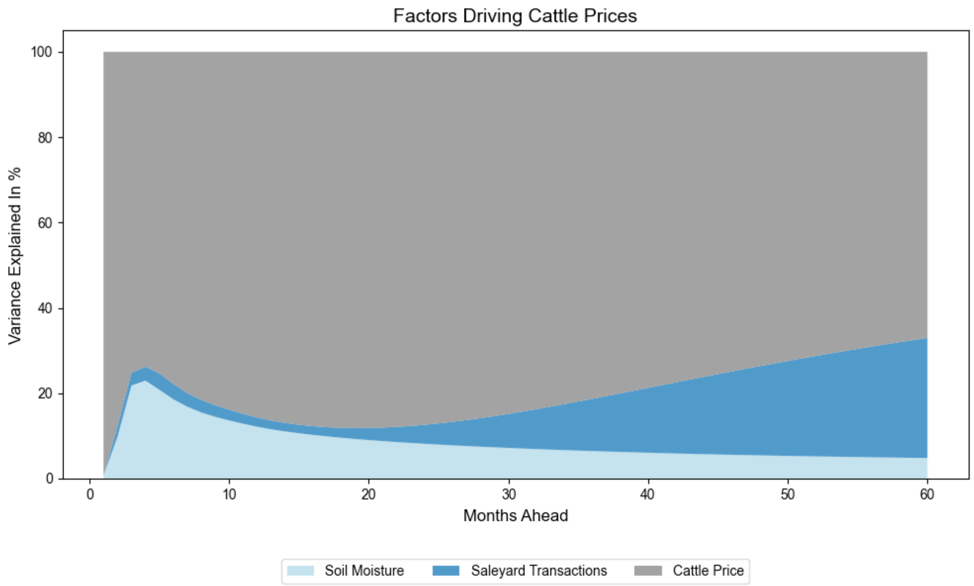
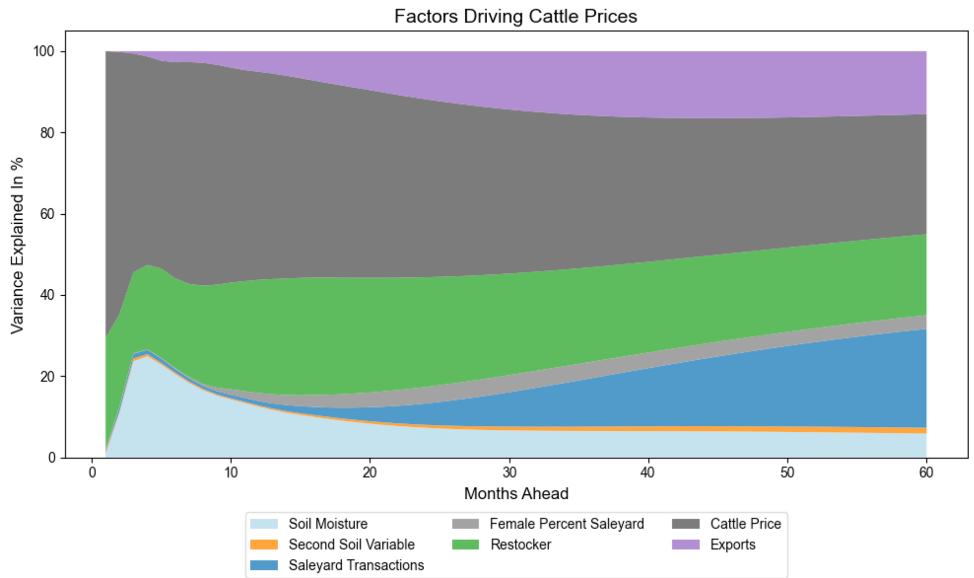


Figure 23. Full Cattle Model with Two Weather Variables: Estimated Soil Moisture Impacts



For lamb, 18.5% and 24.5% of price variability three months ahead can be attributed to precipitation for the restricted (Figure 24) and full model results (Figure 25), respectively. At sixty months ahead, 9.9% and 15.9% of lamb price variability is attributable to precipitation for the restricted and full models.

Figure 24. Restricted Lamb Model: Estimated Soil Moisture Impacts

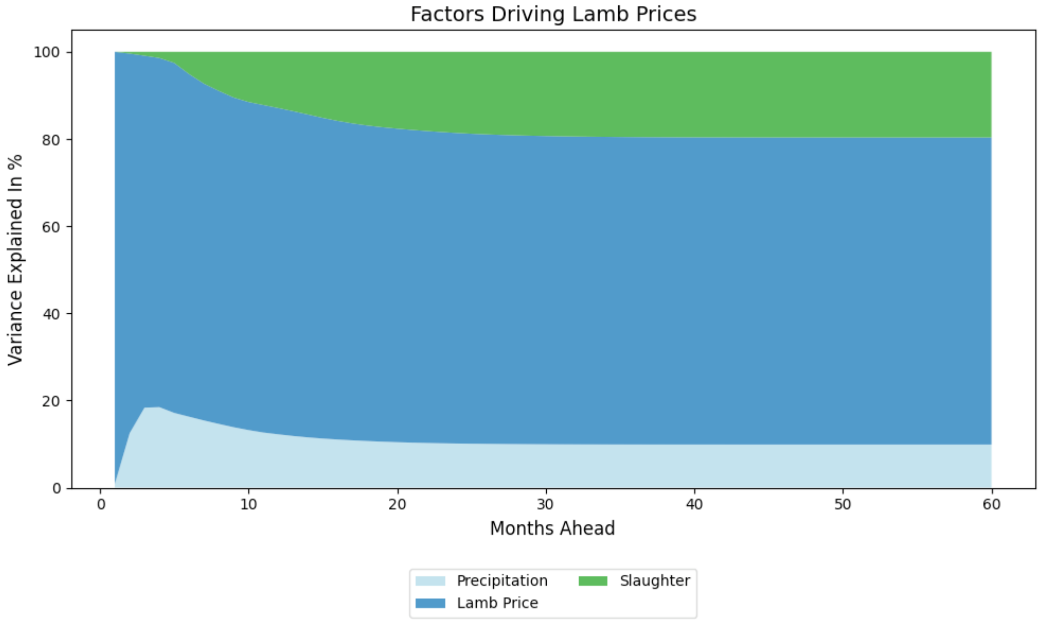


Figure 25. Full Lamb Model with Two Weather Variables: Estimated Precipitation Impacts