AN AGRI-FOOD SUPPLY CHAIN ASSESSMENT FRAMEWORK: APPLICATION TO QUEENSLAND CASE STUDIES

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ABSTRACT: The purpose of this study is to develop a supply chain assessment framework that can be used to describe and analyse agri-food supply chains at an industry level in a systematic manner. This will facilitate comparison and classification between different supply chains. The framework is developed based on a literature review and is demonstrated with two agri-food supply chains (i.e. beef and grain) in Queensland, Australia. Using the developed framework, description, comparison and classification of two supply chains are undertaken. Issues and opportunities within and across these distribution networks are identified. The framework is an instrument that can assist in deriving information for decision making that aims at improving the efficiency and resilience of food distribution systems on an industry scale. It can help identify the growth prospects of agri-food industries in regional Australia and elsewhere.

KEYWORDS: Agri-food, analysis, beef, classification, comparison, description, framework, grain, industry-level, supply chain

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1. INTRODUCTION

Efficient and reliable agri-food (e.g., crops, livestock, and seafood) supply chains are important to ensure the continued provision of food to humans but also for income generation in regions where agri-food is produced. To maintain the supply of agri-food products it is essential that producers and influential stakeholders (e.g., industry bodies) regularly review the processes and the performance within their distribution network. Assessment of the environment in which these supply chains operate (e.g., regulation, market access) also helps to identify longer term structural pressures and changes.

Individual agri-food businesses may undertake an analysis of their product's supply chain to identify whether their distribution network complies with their corporate objectives (e.g., consumer satisfaction, profit maximisation) and strategies to gain a competitive advantage within the market (Chopra, 2007; Ensign, 2001). The extant literature offers a vast range of approaches (e.g., value chain analysis, risk analysis) and criteria (e.g., efficiency, flexibility, responsiveness, agility) that can be applied to analyse agri-food supply chains at an individual business level (Aramyan *et al.*, 2007; Chopra, 2007; Estampe *et al.*, 2013).

Yet, the performance of agri-food supply chains can be affected by a range of external factors (e.g., market information, quality of road network), which are typically not considered in individual business supply chain analyses. As well, agri-food businesses may struggle to evaluate the characteristics of their individual distribution network against industry standards due to the lack of information, skills, or time, or because they consider that their industry and associated supply chains have unique features. This may limit their capacity to compare their supply chain to network structures, processes, and operations of similar industries.

An analysis of agri-food supply chains at an industry level could provide individual producers and other industry stakeholders with information about potential issues (e.g., price bargaining power of mid-supply chain entities, poor road quality or network) and opportunities (e.g., increasing consumer demand, export) at a broader industry scale. Such information can be useful for addressing identified problems and financial returns, which subsequently may contribute to economic growth in rural regions that are dominated by agricultural and seafood production. A comparison of agri-food supply chains allows identification of similarities, differences and weaknesses within their structures and processes. Classification of agri-food supply chains can assist industry managers and government institutions to group agri-food supply chains into different classes and to prioritise investments into addressing issues and opportunities identified for each class.

The available literature is limited in providing approaches that can be used to describe, analyse, compare, and classify agri-food supply chains at an aggregated industry level. The literature only focuses on selected components that are needed for comparison and classification within and across aggregated agri-food supply chains. For example, Fassinou Hotegni *et al.,* (2014) describe the supply chain structure and processes within a single horticulture industry, pineapple, without comparing it to other supply chains. Similarly, Aramyan *et al.,* (2007) offers a description of the supply chains of tomatoes without a comparison to other supply chains. Performance analyses of processes within agri-food supply chains at an industry level have attracted some attention in the literature (Estampe *et al.,* 2013; Gunasekaran *et al.,* 2001; Jie *et al.,* 2015). Yet, more comparative analyses and comparisons of supply chains at an industry level are rare (Carbone, 2018; Plagányi *et al.,* 2014). For example, Howieson *et al.,* (2016) offer a framework to analyse value chains, however, their approach does not allow a comparison and classification of agri-food distribution networks.

Hence, the purpose of this study is to develop a supply chain assessment framework that can be used to describe and analyse agri-food supply chains at an industry level in a systematic manner. The framework will enable comparison and classification of supply chains as well as the identification of issues and opportunities within and across these networks. To demonstrate the approach the framework developed in this study was applied to the distribution networks of beef and grain produced in Queensland, Australia.

The study uses a literature review for to develop the supply chain assessment framework and draws on secondary data sources for the two case studies. The scope of this study is to take a producer perspective on supply chain analysis, implying that agri-food industries and influential stakeholders (e.g., industry bodies, government) strive to optimise agri-food distribution networks to increase the value generated within the network, which is expected to increase the return to agri-food producers.

2. AGRI-FOOD SUPPLY CHAINS

The existing literature offers a wide range of definitions for the concept of an agri-food supply chain as outlined by Routroy *et al.,* (2017). Tsolakis *et al.,* (2014), for example, define an agri-food supply chain as a set of activities which are needed to transfer a farm product from producer to its consumer, which can include processing, testing, packaging, warehousing, transportation, distribution and marketing. Dani (2015) defines an agri-food supply chain as a series of processes, operations and entities which contribute to transferring agri-food goods from its freshly harvested or raw state to its consumers.

Lambert *et al.*, (2000) describe four main attributes of a supply chain:

a) it follows a number of stages in which each additional stage increases the need for intra- and inter-organizational coordination,
b) it includes several independent firms suggesting that an managerial relationship is essential,
c) it involves a bi-directional flow of information, managerial and operational activities, and
d) chain members aim to fulfil the goals to provide high consumer value and an efficient use of resources.

Factors that differentiate an agri-food supply chain from other supply chains are, for example, a) the nature of production which is based of biological processes, thus, prone to high variability and risk, b) the characteristics of the product, such as perishability and bulkiness which require consideration in the supply chain, and c) consumer expectations in regard to food safety and production standards (Aramyan *et al.,* 2006; Lemma *et al.,* 2014).

While each agri-food supply chain is different, there are several common types of entities across them, which typically include:

- production input providers (e.g., equipment, seed, genetics company, technology, capital investment),
- agricultural/seafood producers (e.g., farmers, fishermen, aquaculturists),
- processors/manufacturers (e.g., packing, preparation),
- wholesalers (e.g., distribution),
- retailers (e.g., distribution, marketing and sales), and
- consumers.

Figure 1 offers an illustration of the conceptual system of agri-food supply chains. The figure shows the vertical links between these supply chain entities which indicates the physical flow of the product along the supply chain.

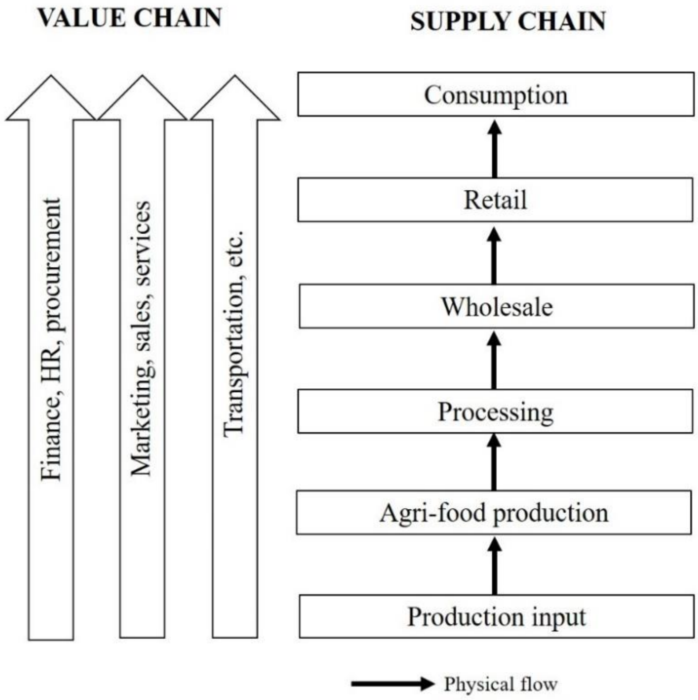

Figure 1. Conceptional System of Agri-food Supply Chains. Source: Adapted from Bourlakis *et al.*, (2004) and Tsolakis *et al.*, (2014).

The term value chain is frequently cited in conjunction with the concept of a supply chain. A value chain is defined as a strategic partnership among interdependent businesses (e.g., farmers, processors, retailers) that collaborate to progressively create or add value to agri-food products for the final consumer (Porter, 1985). The ultimate objective of a value chain is to create a collective competitive advantage in offering a high-quality product which differentiates the chain from its competitors (Porter, 1985). Added value flows within a supply chain (e.g., value generated through processing and transportation) are illustrated in Figure 1 by vertical arrows directed from agri-food producers to the consumers (e.g., processing, transportation).

3. METHODOLOGY

The assessment of agri-food supply chains at an industry level requires a structured evaluation process which allows a description, analysis, comparison and classification of the distribution networks. An agri-food supply chain assessment framework is presented in the following section, which was developed through a literature review. Data for the two case studies were obtained from secondary data sources (e.g., literature review, production statistics).

Agri-food Supply Chain Assessment Framework

For the description, analysis, comparison and classification of agri-food supply chains, an evaluation approach was developed. Figure 2 presents an illustration of this framework. The proposed assessment procedure uses a bottom-up method, implying that individual industry supply chains are first described and analysed before a comparison and classification across supply chains can be undertaken. Hence, the critical component within this assessment approach is the description of agri-food supply chains in a standardised manner, which later allows comparison and classification of supply networks. Each of these steps is described in the following sub-sections.

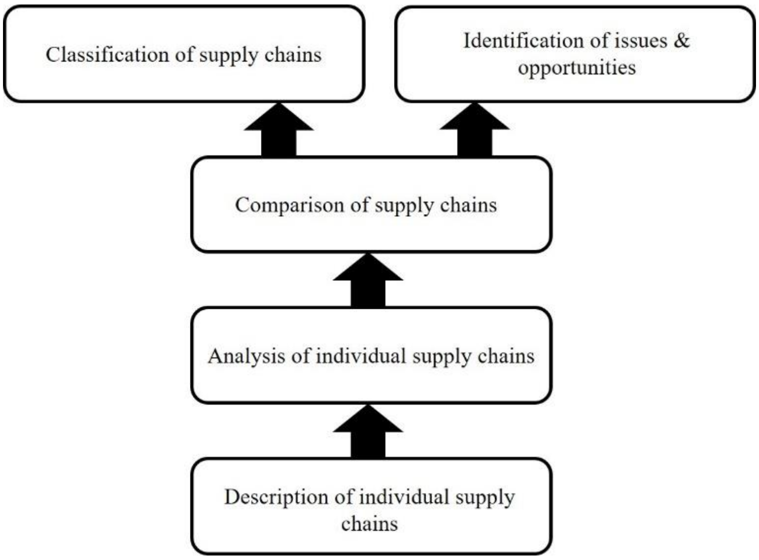

Figure 2. Agri-food Supply Chain Assessment Approach. Source: the Authors.

Description and analysis of individual supply chains

To ensure that the information needed to describe various agri-food supply chains in a standardised manner, the use of the supply chain description matrix as presented in Table 1 may be considered. This matrix summarises information categories such as a) product characteristics, b) mapping of the supply chain (e.g., features, structure and processes), and c) factors affecting supply chains structure and processes. Selected themes considered within each category should be context-specific to ensure that relevant information for a supply chain assessment is collected. The matrix presented in Table 1 was developed based on assessment themes, which were considered important to describe agri-food supply chains in the context of Queensland.

Product characteristics

To describe an agri-food supply chain, it is important to consider the characteristics of the product. This may include information about the food category (e.g., animal protein, grain), perishability, freight type (e.g., bulk, non-bulk), product categories (e.g., primary or secondary) and seasonality (see Table 1).

Supply chain mapping: features, structure & processes

The second category of information required for a description of an agri-food supply chain is the mapping of the supply chain's structure, processes and specific features. Such maps can illustrate the structure of the supply network overall and how entities which operate within a supply chain are connected (Gardner and Cooper, 2003). Supply chain mapping is commonly used to enhance strategic planning processes, facilitate redesign or modification, obtain clarity about network dynamics, enhance communication, enable monitoring of supply chain strategies and to provide a basis for supply chain analysis (Albu *et al.*, 2006; Gardner and Cooper, 2003; Howieson *et al.*, 2016; Kaminski *et al.*, 2018; Making Markets Work Better for the Poor, 2008).

Table 1. Supply Chain Description Matrix. Source: the Authors.

Supply chain assessment themes	Definition	Supply chain for product X
PRODUCT CHARACTERISTCS		
Food category	Determines the food category of the product: Grain, animal protein, dairy, horticulture, seafood, non-food agriculture product.	*to be completed*
Perishability	Determines the perishability characteristic of the product: Perishable, long-life, non-perishable.	…
Freight type	Determines the type of freight of the product: Bulk, non-bulk.	…
Product category	Determines whether a supply chain focusses on a primary or secondary product: Primary good (e.g., unprocessed, fresh), secondary good (e.g., processed).	…
Seasonality	Determines seasons within which product is supplied to the market: Summer, spring, autumn, winter.	…
SUPPLY CHAIN MAPPING: FEATURES (F), STRUCTURE (S) & PROCESSES (P)		
Required chain features (F)	Determines required features of the chain: Cold chain, fresh/cut, storage.	*to be completed*
Market distance / supply proportion (S)	Determines the market distance or spatial distance between consumers and producers of a good as well as the proportion supplied to different markets: Local (<100km from production location), domestic (<100km from production location), export.	…
Supply chain structure (“changes of hands”) (S)	Maps the tiers/entities which perform physical activities along the supply chain as well as their connections with each other and proportional product volume distributed within the network.	…
Value creation (P)	Maps the stepwise creation of value between producer and consumer ($/unit).	…
Cost creation (P)	Maps the stepwise creation of costs (incl. transaction costs) between producers and consumers ($/unit).	…
Lead-time (P)	Maps the latency between the initiation and execution of a process along the supply chain (hours/activity).	…
Relationships (P)	Determines the presence/type and maps the collaboration/coordination within the supply chain: None, level of vertical integration (# of businesses involved), horizontal integration (# of businesses involved), hybrid (# of businesses involved).	…
Power distribution / Dominance (P)	Maps the power distribution (e.g., price bargaining power) of entities within supply chains.	…
Traceability (F)	Determines the type and level of product traceability along the supply chain.	…
Sustainability (F)	Determines sustainability aspects of the supply chain (e.g., sustainability of production, transportation, food loss, waste).	…
FACTORS AFFECTING SUPPLY CHAIN STRUCTURE & PROCESSES		
Market information & market access	Provides information about the role of market information and market access and its impact on structure, processes & performance of supply chains: Consumer demand, consumer characteristics, access to markets, competition, product marketing.	*to be completed*
Capacity	Provides information about the role of capacity and its impact on structure, processes & performance supply chains: Labour characteristics, size of producers, availability & quality of infrastructure, level of technology adoption/need for advanced technology to be developed, availability of resources.	…
External factors	Provides information about the role of external factors and its impact on structure, processes & performance: Production risks, regulation, government as facilitator, investors, R&D, industry organizations.	…

The mapping of supply chain structure and processes should be conducted using different thematic foci where the selection depends on the purpose of the mapping task (Gardner and Cooper, 2003; Jaffee *et al.,* 2010). Such thematic foci may include supply chain network/structure mapping (Fassinou Hotegni *et al.,* 2014), cost stream mapping (including transaction cost mapping (Hobbs, 1996; Mena *et al.,* 2013), value stream mapping (Taylor, 2005), lead time and logistics mapping, and entity dominance mapping (Plagányi *et al.,* 2014). Product traceability and sustainability aspects are features of agri-food distribution networks that are increasingly becoming important (Aung *et al.,* 2014; Gardner *et al.,* 2019). The assessment of supply chain governance processes, such as relationships among supply chain players (e.g., collaborative or coordination), may also be of interest for the analyst (Denolf *et al.,* 2015; Zhang *et al.,* 2009). Defining the thematic foci for the supply chain structure and process mapping task is particularly important if a comparison of different supply chains is to be undertaken. Furthermore, a systematic approach, such as the use of standardised mapping templates, will allow a structured analysis and comparison of supply chains at a later stage of the assessment.

Although there are compelling reasons for mapping supply chains and processes, there are also risks associated with it. For example, the inability to capture changes of a chain or processes over time, getting lost in detail, provision of ineffective perspective for management use or giving away competitive information are all potential risks.

Factors affecting supply chain structure & processes

A further step in describing agri-food supply chains is the identification of factors which can affect their structure and performance. This can be referred to as the enabling environment within which a supply chain operates (Albu and Griffith, 2006; Goesch *et al.,* 2015; Laosirihongthong *et al.,* 2013; Nyamah *et al.,* 2017) (see Figure 1 and Figure 3). These enabling factors can broadly be categorised into:

a) market information and market access (e.g., characteristics, demand and supply (Grunert, 2005; Markelova *et al.,* 2009; Spencer *et al.,* 2012);

b) capacity (e.g., labour characteristics within the supply chain, size of producers, availability of infrastructure and financial capital, level of technology adoption, and availability of natural resources); and

c) external factors (e.g., production risk such as pests/diseases, drought, government regulation, facilitation of market access, government investment in infrastructures such as roads and ports, investors, economic situation, investment into research and development (Goesch *et al.*, 2015; James *et al.*, 2007; Martin *et al.*, 2015) (see Figure 3).

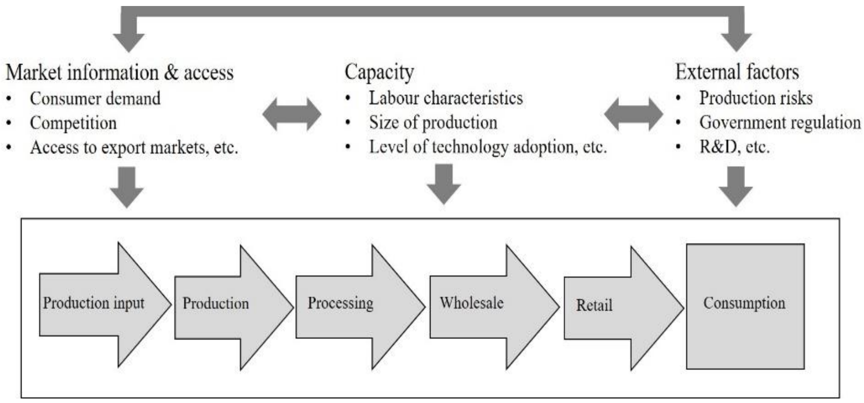

Figure 3. Factors Affecting Supply Chain's Structure and Processes. Source: the Authors.

Some of these factors can be considered as risks for the performance of a supply chain, such as weather-related risks, biological and environmental risks, market risks, and public policy risks (Jaffee *et al.*, 2010). These factors can not only affect the supply chains of agri-food products but to some degree also affect other factors which form part of an enabling environment for supply chains (e.g., the role of government in enabling market access, the role of labour in analysing consumer demand and develop marketing strategies). Hence, an understanding of the environment in which a supply chain is established is important to identify potential barriers which may prevent the improvement of supply chains.

Analysis of individual supply chains

After the description of an individual supply chain is completed, the collected information is to be analysed (Figure 2). The aim of an individual supply chain analysis is to gain an advanced understanding about the key characteristics of the chain and influencing factors, which provide the basis for a comparison across several agri-food supply chains.

The analysis can be conducted using multiple methods. For example, a visual examination can identify specific structural features of a supply chain (e.g., network levels and complexity, dominance). A value chain analysis can be conducted by calculating the incremental value changes of the product based on the progression through the network. A similar analysis can be undertaken for cost increments within a supply chain.

A conventional supply chain performance analysis, which focuses on metrics such as efficiency, responsiveness, flexibility, profit, and waste elimination (Aramyan *et al.,* 2006; Aramyan *et al.,* 2007) requires individual agri-business data. Due to the aggregated perspective of the assessment of supply chains (industry level instead of agri-business level) in the context of this study and the excessive business data requirements, such a performance analysis is not feasible.

There are other options to analyse selected features of supply chains while maintaining an empirical approach. For example, to analyse critical elements within a seafood supply chain in Australia, Plagányi *et al.,* (2014) first used a standardised template to develop supply chain models (maps) for different seafood products. Importantly, quantities of the product that flow to each receiving element within the chain to the next were included in these models. Based on these supply chain models, Plagányi *et al.,* (2014) then developed a supply chain index that identifies critical elements as those elements with large throughput rates as well as those having greater connectivity. The identification of such key elements within supply chains can also be used for a comparison of critical features across agri-food supply chains.

Comparison and classification of supply chains

Following the analysis of individual supply chains, findings can be used to compare various agri-food supply networks (Figure 2). The comparison can be conducted in different ways, for example, by visually comparing supply chain structures or comparing the values created within multiple cost and value chains. A comparison of the facilitating environment may also be undertaken. Reasons for differences or similarities across supply chains may be explained by the product characteristics or factors that influence the supply chain's structure and processes (see Table 1).

According to the identified similarities and dissimilarities, supply chains may be classified based on specific features, e.g., connectivity, similar critical elements, perishability and complexity. Furthermore, an identification of individual or common issues and opportunities can be derived from comparing supply chains. This is expected to contribute to the process of optimising current agri-food supply chains.

4. CASE STUDIES

To illustrate the value of the developed supply chain assessment framework (Figure 2) as an instrument to systematically describe, analyse, compare and classify agri-food distribution networks, it is applied to two case studies in Queensland.

Queensland produces a range of agri-food products, including livestock (e.g., beef cattle, poultry and fish), crops (e.g., grains, cotton lint, sugar cane), and horticulture commodities (e.g., tropical fruits, vegetables, nuts), which generates employment for about 57,000 people (Department of Ariculture and Fisheries (DAF), 2018). The economic value that Queensland's agri-food sector generated in 2018/19 was about $13 billion, which accounted for 21% of the total gross value of agricultural production in Australia (A$60 billion) (Australian Bureau of Statistics (ABS), 2020b).

The beef and grain supply chains were selected as case studies due to both commodities' important role in Queensland's agri-food sector. Furthermore, the choice of the case studies was also guided by the availability of sufficient secondary data (e.g., literature, industry statistics) about the distribution networks. An additional case study about the pineapple supply chain is offered in the supplementary document.

Description and Analysis of Individual Supply Chains

For the description and analysis of the beef and grain distribution networks, the agri-food supply chain description matrix (Table 1) was applied. Results are shown in Table A.1 in the Appendix. The following sections offer a brief description and analysis of the individual distribution networks.

Beef supply chain

Queensland is the largest producer of beef cattle in Australia (Ernst and Young Australia, 2018; Goesch *et al.*, 2015) and the beef cattle industry is the largest agri-food industry in Queensland (DAF, 2018). The industry generated an economic value of about A$5.8 billion in 2018/19 (ABS, 2020b).

The supply chain map for beef is shown in Figure 4 which illustrates that the production segment within the beef supply chain involves several stages before the animals are transferred to processors. Queensland's beef production is based on two production systems, cattle breeding operations (mostly in northern regions) and fattening systems (mostly in southern regions) with the animals being transferred across these system within their life cycle (Ernst & Young Australia, 2018). Saleyards are often (but not always) first points of cattle aggregation in the beef supply chain and provide a venue for transferring both feeder and finished stock. Pastures, crops and feedlots (e.g., by grain feeding) are used in fattening systems for beef production (Ernst & Young Australia, 2018). Feedlots can be either operated as separate businesses or can be vertically integrated with producers or processors (Figure 4) (Ernst & Young Australia, 2018). This gives greater control over the quality and timing of supply than is possible with grass finishing (Goesch *et al.,* 2015).

From these entities within the production stage of the supply chain, the cattle may be transferred to abattoirs for processing, sometimes through saleyards as intermediates. Most of the abattoirs are located in south-east Queensland (Goesch *et al.,* 2015), which means that the cattle need to be transported, mostly via road, over long distances. Major processors in Queensland are JBS Australia, Teys Australia, and NH Foods Australia (Ernst & Young Australia, 2018). From the abattoirs, the beef is transferred to wholesalers and then distributed within the retail sector, e.g., butcheries, retails stores and food services. From there the beef product is supplied to consumers.

Within the domestic market, some beef is also supplied as a high premium product with unique characteristics (e.g., specific breed or brand), which is called branded beef. In some cases, beef products are described by non-visible factors (credence factors) to describe animal welfare, organic or other provenance factors. These specialised beef products follow a slightly different supply chain than regular beef products. Cattle that are used for specialty branded beef are typically transferred to specialty abattoirs or butcheries for slaughtering and are then distributed to the retail sector like regular beef products (Figure 4).

Beef is exported in two forms from Queensland: as processed beef and as live exports. Processors that prepare meat products for export markets are required to hold export certification and accreditation (Ernst & Young Australia, 2018). For processed exports, the beef is transferred as either chilled or frozen product from abattoirs via road or rail in refrigerated containers to a Queensland port (Figure 4). The majority of processed beef is exported through the Port of Brisbane (Goesch *et al.*, 2015). The refrigerated containers are loaded on vessels and shipped overseas. Major importers of Australian processed beef are Japan, the USA, Korea and China (Goesch *et al.*, 2015). At the overseas port, the containers are transferred to importers/wholesalers and then distributed to overseas retail outlets, such as butcheries, retail stores and food services, which supply the products to consumers.

Worldwide, Australia is one of the largest live exporters of cattle (Ernst and Young Australia, 2018). The majority of live exports is feeder and slaughter cattle (89%), with only a minor export volume of breeder cattle (11%) (Ernst & Young Australia, 2018). The supply chain for live export of cattle starts at the properties where cattle are raised, although some are transferred to other properties for export conditioning. From there, the cattle are sent to the Townsville port terminal. Townsville is the largest live export terminal in Queensland. The cattle are inspected for compliance with export regulations before they are loaded onto specific vessels and shipped overseas. The main countries importing Australian cattle are Indonesia and Vietnam (Goesch *et al.*, 2015). From the overseas port terminal, the cattle are transferred to feedlots for recovery and fattening before they are transported to an abattoir for slaughtering and processing. From the abattoir, the beef is forwarded to wholesalers who distribute the beef to the retail sector, e.g., butcheries, retails stores and food service providers.

The beef supply chain is relatively complex since it involves features such as cattle-handing, cold chain and live export infrastructure. Furthermore, the supply network is multi-layered, meaning that there are several alternatives which connect producers and consumers of beef. Figure 4 shows that a dominant role within the beef supply chain is held by the processors.

However, there is some collaboration within the beef supply chain existing, predominantly between producers as well as between producers and processors (Goesch *et al.*, 2015). Consumer demand for beef in Australia is decreasing (e.g., less red meat consumption) but demand from overseas remains strong (Meat and Livestock Australia (MLA), 2020). Consumer awareness about the credence aspects of beef production is increasing, specifically regarding the live export of cattle fuelled by concerns about animal welfare (Goesch *et al.,* 2015) and the impact of production on the environment (MLA, 2020).

The export of beef is affected by market access, overseas demand for Australian beef, and the fluctuation of the exchange rate of the Australian Dollar to currencies of countries to which Queensland export the products.

Since Queensland is the largest producer of beef cattle in Australia, the supply chain information presented in this study can be considered Australian best practice. However, reoccurring animal welfare issues that are associated with live export of cattle to Asia remains an area that requires continued improvement and regulatory controls, specifically since negative media attention may affect domestic and overseas demand for beef (Petherick, 2005).

The performance of the beef production and subsequent market supply of beef is significantly affected by rainfall and stocking rates since the lack of rainfall affects the availability of cattle feed and subsequent reproduction rates (Ernst & Young Australia, 2018). This impacts breeding operations and the overall productivity of beef production (Ernst & Young Australia, 2018). The adoption of technology in the production system but also within the rest of the beef supply chain (e.g., improved product traceability based on mandatory adoption of National Livestock Identification System) underpins food quality and safety programs adopted by the beef industry (Ernst & Young Australia, 2018).

Grain supply chain

In 2018/19, Queensland produced about 2% of Australia's total winter crop (e.g., wheat, barley, chickpeas) volume and about 52% of the summer crop volume (e.g., sorghum) (Australian Bureau of Agricultural and Resource Economics (ABARES), 2020). Sorghum production in Queensland accounted for about 44% of the total grain output volume, followed by wheat (20%), cottonseed (11%) and chickpeas 6% (ABARES, 2020; DAF, 2018). Grains are mostly produced in the south-west and central regions of Queensland. The grain industry in Queensland generated an economic value of about A$600 million in 2018/19 by producing approximately 1.6 million tonnes (ABS, 2020a, 2020b).

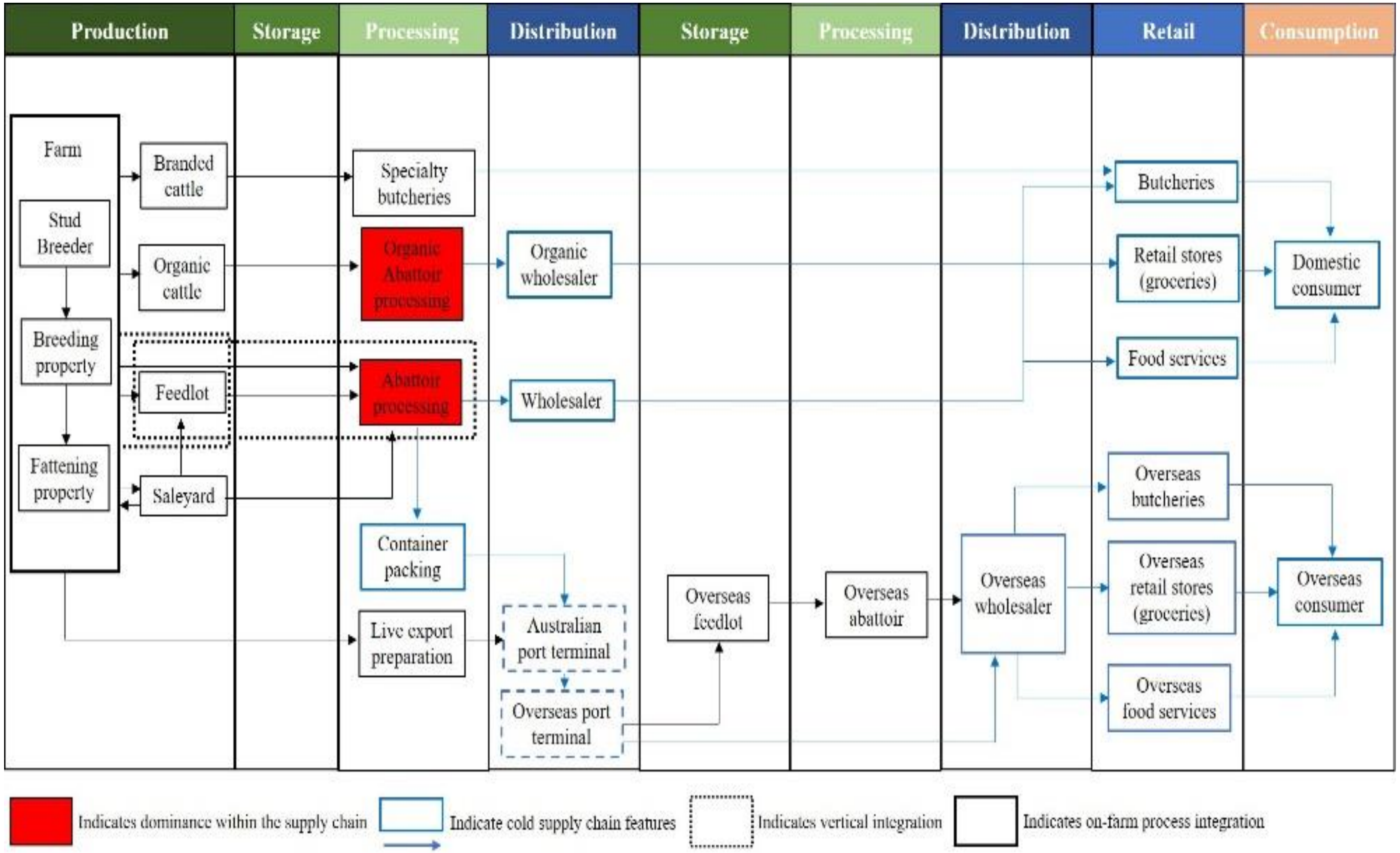

Figure 4. Beef Supply Chain Map. Source: the Authors.

A structural supply chain map for grain (excluding cotton lint and cottonseed) produced in Queensland is presented in Figure 5. While grain is supplied to the domestic market, most of this agri-food product is exported to countries such as India, Pakistan, China, and Bangladesh (Australian Export Grains Innovation Centre (AEGIC), 2018; DAF, 2018). Grain is an input for various products, which is the reason why the supply chain of grain is differentiated into several segments. The grain supply chain starts with inputs to production that includes seed and fertilizers which can be obtained domestically or from the overseas market (Figure 5). In Queensland winter crops (e.g., wheat, barley, chickpeas) are usually planted in March and are harvested between October to December. Summer crops (e.g., sorghum) are commonly planted in September and harvested between February and May. For both crop types, the planting and harvest periods are determined by rainfall.

After harvest, the grain is either stored on-farm in silos and then transferred to local receival points for storage or directly supplied by farms to these central receival/storage facilities (AEGIC, 2018). Nguyen *et al.*, (2015) estimated that most of the total grain volume produced in Queensland is directly transferred from the farms to local receival points rather than being stored on-farm. GrainCorp is the largest grain handler and export facilitator in Queensland (AEGIC, 2018). About half of the grain that is designated for export is sent to port containerisation facilities for export preparation and is then transported to an export terminal at one of the four grain exporting ports in Queensland (AEGIC, 2018). The other half of export grain is loaded onto bulk vessels (AEGIC, 2018).

Before the grain is exported it is inspected for compliance with export regulations (AEGIC, 2018). After arrival at the overseas port terminal the grain is stored and either transferred to processing plants or directly to wholesalers. Products that are produced from grain are transferred to wholesalers who then distribute the products to overseas bakeries and retail stores for subsequent supply to consumers.

The domestic grain supply chain separates from the export chain at the local receival points or at the on-farm storage stage (AEGIC, 2018; Ensign, 2001). From here, the grain is forwarded to domestic processing plants (mills), where the grain is transformed into flour. The flour is transported to wholesalers and then transferred to processing facilities at which the flour is transformed into products, such as bread, pasta, cake. From the processing facility, the final products are either directly transferred to the retail sector or first forwarded to wholesalers and then distributed to the retail sector, which supplies the products to the domestic consumers.

Domestically, grain (particularly sorghum) is also used for feedlots to feed/fatten animals (e.g., cattle, pigs, poultry) and for animal food (e.g., pets) (AEGIC, 2018; Nguyen *et al.*, 2015). The supply chain that links grain producers and domestic feedlots/animal food consumers can include on-farm storage or local receival point storage, processors (e.g., fodder production), wholesalers and retailers (e.g., typically only for smaller volume units). Alternatively, grain may also be supplied directly from the storage facility to feedlots (see Figure 5).

Grain produced in Queensland (mostly wheat, sorghum and corn) is also used for the production of biofuel, which is supplied to the domestic market (Nguyen *et al.*, 2015; O'Connell *et al.*, 2007). The supply chain for biofuel separates from other grain-based product's supply chains at the on-farm storage or local receival point stage. From storage facilities, grain is transferred to biomass processing plants (not located in Queensland) where the grain undergoes grinding and is transformed into biofuels (e.g., ethanol and biodiesel), which is then blended with crude oil-based fuels (O'Connell *et al.*, 2007; Queensland Transport and Logistics Council (QTLC), 2013). From the processing plant, the fuel is transferred to wholesalers and then distributed to petrol stations (retail), which supply consumers with fuel.

Given the versatile use of grain as an input to products such as human food, animal food, and biofuel, and the supply of these products to domestic and export markets, the grains supply chain displays multi-layer features and includes a large number of entities which are connected through a relatively complex network.

Value in each of the sub-supply chains of grain is mostly created through storage, transportation and processing. Key influences on cost creation within the chain include distance to the port, the efficiency of receival and storage, duration of storage, type of haulage, ease of ship loading, time of shipping and port charges (AEGIC, 2018). In most cases, freight to the nearest port is the major component of the supply chain's total cost (AEGIC, 2018). Detailed information about financial value added at each stage of the grain supply was not available for this study.

Figure 5 shows that the local receival points, which are owned by influential handling and export facilitators, hold a powerful position within the grain supply chain. The Australian Competition and Consumer Commission (ACCC) has raised concerns about the dominant role of handing and export facilitators within the grain supply chain and is monitoring their operations (AEGIC, 2018). Other issues that affect the grain supply chain are production risks such as weather, pests and also the

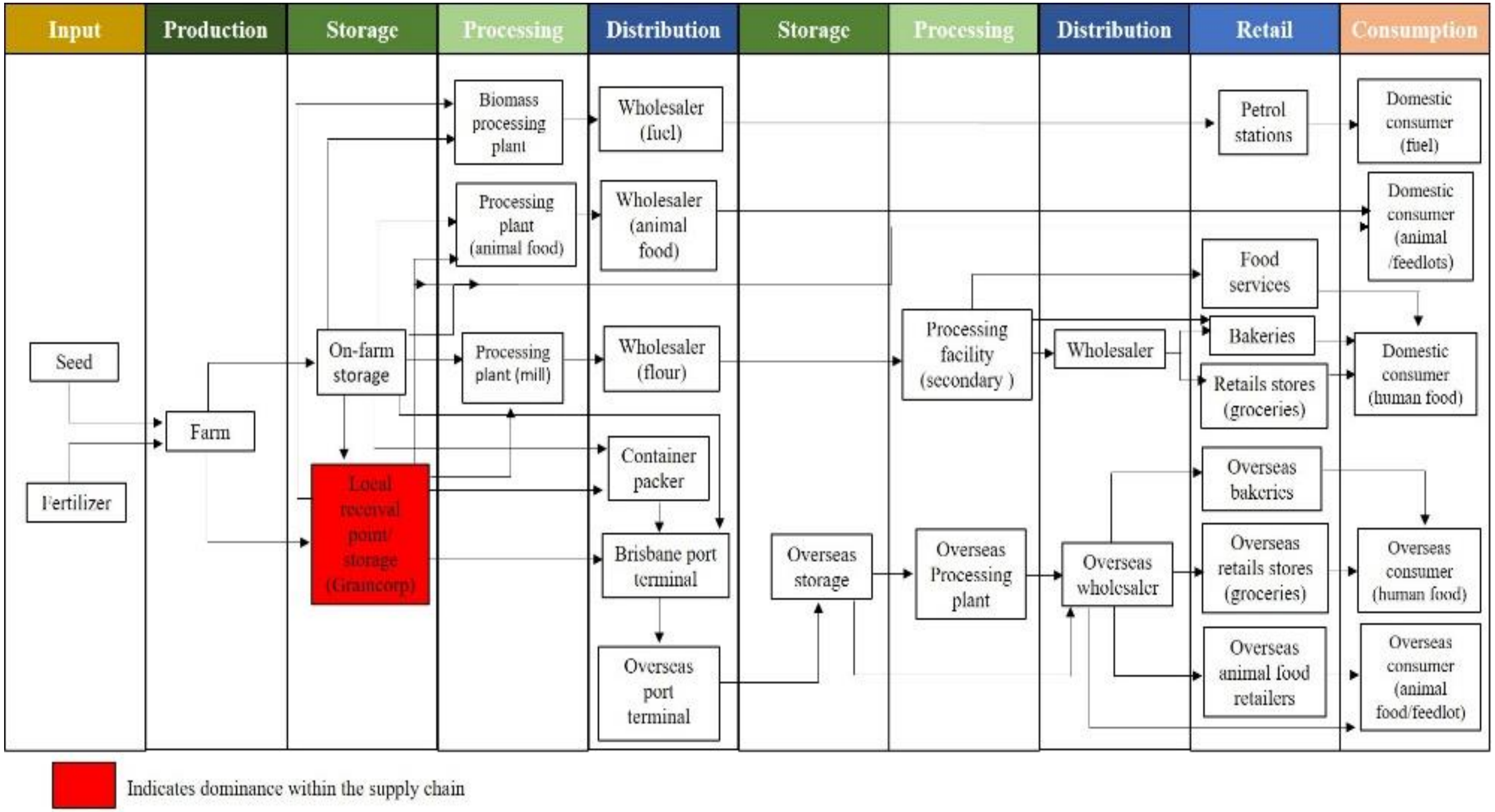

Figure 5. Grain Supply Chain Map. Source: the Authors.

road network as well as limitations on road capacity (AEGIC, 2018; Nguyen *et al.*, 2015).

Since Queensland exports most of the grain it produces it is affected by global competition from countries such as Russia, Ukraine, the USA, Canada, and Argentina, which affects the prices and returns to the Australian grain industry. Furthermore, the exchange rate of the Australian dollar has an impact on the demand for Australian grain and hence the returns to the businesses which operate within the supply chain.

The structure and processes within the grain supply chain in Queensland do not differ significantly from grain supply chains in other grain producing states of Australia (AEGIC, 2018; Nguyen *et al.*, 2015). This is due to the production of relatively uniform grain products throughout Australia's grain growing regions.

As for the beef supply chain, there are gaps in the literature about assessment themes such as cost creation, product traceability and sustainability for the grain supply chain.

Comparison and classification of supply chains

Comparison

Given the individual description and analysis of the two supply chains, it is now possible to compare the networks, to classify them and to identify issues and opportunities.

A comparison of the distribution networks indicates that beef and grain supply chains both display features of multi-layered open networks (e.g., presence of sub-networks, absence of recycling or after-consumption collection/use (Gong *et al.*, 2018; Mena *et al.*, 2013)) with a very large number of entities being part of this network (see Figure 4 and Figure 5).

These supply chain features may be explained by the production scale, the variety of products for which grain is used as an input and the varying product characteristics of beef (e.g., live cattle, processed beef cuts). Furthermore, production areas of both commodities are predominately located in inland regions of Queensland with large distances between production areas, domestic processing markets as well as transport infrastructure such as ports. Both networks include product export and are subsequently affected by potential market access issues and exchange rate fluctuations.

The comparison of the supply chains identified that there are concentration points in both networks, such as the processing stage for beef and the initial off-farm storage stage for grain (Figure 4, Figure 5). These concentration points within the supply network help to standardise systems and provide focus points for coordination, but they also allow some players to have excess market power. Balancing these different requirements is an ongoing challenge.

A difference between the beef and grain supply chains is their requirements for product cooling (Table 1). The grain supply chain does not require any cooling, while the beef supply chain demands a mix of ambient (cattle, before processing) and cooling (after processing) features.

There is also a difference in the requirements for physical infrastructure within the grain (storage silos) and beef (procession facilities) supply chain.

Classification

Given the findings from the comparison of the two case studies, only one supply chain class could be identified, that is a multi-layered supply chain that has established export segments of industries that generate large volumes of the product in areas that are predominately located in rural areas.

The analysis demonstrates that the supply chains for large commodities such as beef and grain are diverse and sophisticated, operating across multiple stages and multiple markets. The different markets involved provide forms of internal competition and potential substitution that helps to stimulate ongoing searches for efficiency. However, the multiple stages involved in the supply chains make it difficult to identify the large potential for major efficiency gains, although ongoing improvements in production, processing and transport remain important. Productivity gains are most likely to come from developing and applying new technologies than simply improving current systems. Technological advances are likely to be important for improving farm inputs and farm production, as well as transport and processing systems, and for better matching consumer needs to production systems.

In contrast, agri-food supply chains that predominantly focus on the supply to the domestic market, such as for oysters (Plagányi *et al.*, 2014) and pineapples (see supplementary document) tend to exhibit more simple features, which may be due to the production volume of these industries. To gain a broader understanding about the classes of agri-food supply chains in Queensland further case studies should be undertaken.

Issues and opportunities

There are common and individual issues and opportunities of agri-food supply chains in Queensland. For example, the road network and quality of roads have been identified by the beef and grain industry as challenges to their supply chains (AEGIC, 2018). As export supply chains, the beef and grain industry are also facing the challenges of maintaining market access, competition in the global market and fluctuations of the Australian Dollar, which affect the value of the exported products.

Individual supply chain issues can also be identified for each agri-food product. For example, the beef industry is concerned about a potential future decrease in consumer demand for beef due to potential increasing market supply of plant-based meat substitutes and increasing consumer awareness about environmental and animal welfare aspects of beef production (MLA, 2020; Red Meat Advisory Council, 2015). The requirement for large processing facilities due to food safety regulations and increased pressure on live export requirements (animal welfare) highlights that scope for improvements in the beef supply chain is potentially in the access to markets for processed beef, improved branding of credence characteristics and increased processing facilities to enable this.

For grain, the dominant role within the ownership of local receival points in Queensland (Figure 5) will need to be monitored to ensure that existing market power is not misused.

Opportunities for supply chain improvements were mostly identified at an individual industry level. For the beef industry, increasing the live export volume of cattle to Asia may be a medium-term strategy to counterbalance decreasing demand for beef in other market segments (e.g., domestic metropolitan areas). The grain industry appears to have already developed a well-established export supply chain which will cater for the future demand for grain-based food from developing Asian countries. The growing wheat noodle market and increased use of wheat-based products in developing economies allow for diversity in the export segment of the grain supply chain.

5. CONCLUSIONS

This study introduces a conceptual supply chain assessment framework that can be used to describe, analyse, compare and classify agri-food supply chains on an industry level. A central part of this framework is a supply chain description matrix which offers a standardised template for data collection about different agri-food supply networks.

Findings from the application of this framework to the beef and grain supply chain in Queensland demonstrate the value of the systematic supply chain assessment approach which the framework offers (e.g., identification of similarities and differences, issues and opportunities).

A limitation of this study is the reliance on secondary data for the two case studies. Primary data collection (e.g., interviews with supply chain stakeholders) in addition to a literature review would allow a more detailed analysis and subsequently more comprehensive information about the supply networks. Furthermore, to understand broader issues and opportunities of agri-food supply chains, more case studies should be examined.

Overall, the developed supply chain framework is an instrument that can assist in deriving information for decision making that aims at improving the efficiency and resilience of food distribution networks and growth prospects of agri-food industries and their stakeholders in regional Australia and elsewhere.

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APPENDIX

Table A1. Application of the Supply Chain Description Matrix to Agri-food Products from Queensland (QLD). Source: Data sources are described below.

Supply chain assessment themes	Supply Chain 1 Beef	Supply Chain 2 Grain (e.g., sorghum, wheat, chickpeas)
PRODUCT CHARACTERISTICS		
Food category	Animal protein	Grain
Perishability	Perishable	Long-life
Packaging	Non-bulk	Bulk
Product category	Primary	Secondary (human food, animal feed, biofuel)
Seasonality	Grow out time depends on product (e.g., beef, veal). Slaughter of cattle more during dry season but there is a supply from farms all year round.	Winter crops (e.g., wheat, barley, chickpeas) are planted in March & harvested between October - December. Sommer crops (e.g., sorghum) are planted in September & harvested between February – May (ABARES, 2020; AEGIC, 2018).
MAPPING SUPPLY CHAIN: FEATURES (F), STRUCTURE (S) and PROCEDURES (P)		
Required chain features (F)	Cattle-handing infrastructure, cold chain after slaughter/processing.	Bulk storage or handling facilities (AEGIC, 2018).
Market distance/supply proportion (S)	Domestic: 30%, Export: 70%.	Domestic: 10%, Export: 90%.
Supply chain structure (“changes of hands”) (S)	Large number of entities. Multi-layered supply chain (e.g., conventional beef, branded and organic beef, live export) (see Figure 4).	Very large number of entities. Multi-layered supply chain due to versatile use of grain as input to production (human food, animal feed, biofuel) and different markets (domestic, export) (see Figure 5) (ABARES, 2020; AEGIC, 2018).
Value creation (P)	The Eastern Young Cattle Index (EYCI) which is a 7-day rolling average of young cattle from 25 yards across QLD, NSW & VIC was 487 cents per kilo dressed weight (MLA June 2019), Australian Beef T-bone sells at $24/kg at retail stores.	Farmgate price over the 2018/19 growing season in QLD was $344.51 per tonne (GrainCorp) across all classes. Storage & warehousing $1.65 per tonne (GrainCorp). Overall, a loaf of bread that contains other inputs sells at $3.50/unit at retail store.
Cost creation (P)	Larger operations benefit from lower marginal costs (Ernst & Young Australia, 2018)	n/a
Lead-time (P)	2-3 years growing periods for steers, processing 6 weeks, retail 1 week.	6 months growing the grain, 6 months storage/ processing loaf of bread 12 months.
Relationships (P)	Mostly horizontal integration at different levels of the supply chain. Hundreds of producers. A few feed lotters. Approx. 15 abattoirs – most in south-east QLD. A couple of supermarkets, lots of butchers.	
Power distribution / Dominance (P)	Power held by processors and large retailers (see Figure 4).	Power held by GrainCorp which owns the key infrastructure: delivery sites, silos, parts of rail networks (initial off-farm storage, see Figure 5) (AEGIC, 2018).
Traceability (F)	n/a	n/a

Supply chain assessment themes	**Supply Chain 1 Beef**	**Supply Chain 2 Grain (e.g., sorghum, wheat, chickpeas)**
Sustainability (F)	n/a	n/a
FACTROS AFFECTING SUPPLY CHAIN STRUCTURE & PROCESSES		
Market information & market access	QLD beef cattle industry is the largest in AUS (Ernst & Young Australia, 2018). In 2018/19, QLD beef cattle production generated a value of approximately A$5.8 billion (ABS, 2020b). Large export volumes to Korea & Japan as boxed beef, live export to Vietnam & Indonesia. Changing consumer demands (e.g., less red meat consumption, increasing importance credence characteristics) (MLA, 2020; RMAC, 2015). Strong industry representation through Red Meat Advisory Council and Meat & Livestock Australia which provide support by offering market information and research and development. Strong global competition for exported beef (e.g., Brazil, Argentina) but proximity to Asia is considered as an advantage. Access to market can be an issue depending on country and trade agreements. The exchange rate of the Australian dollar affects demand for Australian beef. Animal health & welfare concerns raised of live exports (Petherick, 2005).	About 1.6 million tonnes of grain was produced in QLD in 2018/19 at a value of approximately A$600 million (ABS, 2020a, 2020b). The industry body GDRC provides market information to farmers & so do growers services such as agronomists, re-sellers, and marketers for GrainCorp. Trade-offs between grain products of biofuels vs. food/feed production. High competition on world market from Russia, Ukraine, USA, Canada, Argentina (AEGIC, 2018). The exchange rate of the Australian Dollar affects demand for Australian grain.
Capacity	Highly sophisticated production system (e.g., grazing, feed lotting, breeding). Mostly medium-large producers. Road network & quality is an issue & adds to logistic costs (most abattoirs located in south-east QLD).	Medium-large scale producers. Expensive storage infrastructure means that monopolies exist. ACCC has raised concern about market structures in grain supply chain (role of handing and export facilitators) (AEGIC, 2018).
External factors	Production risk includes mostly weather (drought or flood) and diseases. Poor road network and quality affect freight costs. Long distances between frames and abattoirs and ports. Rail network is limited. Meat and Livestock Australia (MLA) is the industry peak body involved in market analysis, research and advocacy. Increased technology adoption to improve the production system and food quality & safety (some is mandatory) (Ernst & Young Australia, 2018).	Production risk in terms of crop failure, insect and rodent plague, high capital costs the whole way through the supply chain. Changing consumer trends. Poor rail network, issues with road infrastructure and regulation to allow high-capacity vehicles to achieve end-to-end transport (AEGIC, 2018). Supported by the Grains Research and Development Corporation (GRDC). Limited by space (land).