

COVID-19 and the Agri-Food System in the United States and Canada

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Abstract

Agri-food supply chains in North America have become remarkably efficient, supplying an unprecedented variety of items at the lowest possible cost. However, the initial stages of the COVID-19 pandemic and the near-total temporary loss of the foodservice distribution channel, exposed a vulnerability that many found surprising. Instead of continued shortages, however, the agri-food sector has since moved back to near normal conditions with prices and production levels similar to those typically observed in years prior to the pandemic. Ironically, the specialization in most food supply chains designed for “just-in-time” delivery to specific customers with no reserve capacity, which led to the initial disruptions, may have also been responsible for its rapid rebound. A common theme in assessing the impacts across the six commodities examined is the growing importance of understanding the whole supply chain.

Over the longer term, a continuation of the pandemic could push the supply chain toward greater consolidation of firms and diversification of products given the increasing option value of maintaining flexibility. Other structural changes will be felt through input markets, most notably labour, as the trend toward greater automation will continue to accelerate as a response to meeting concerns about a consistent supply of healthy and productive workers. The economic fall out from the pandemic may lead to greater concentration in the sector as some firms are not able to survive the downturn and changes in consumer food buying behaviour, including movement toward online shopping and enhanced demand for attributes associated with resiliency, such as local. On the other hand, online shopping may provide opportunities for small producers and processors to shorten supply chains and reach customers directly. In the long term, COVID-19 impacts on global commerce and developing country production are more uncertain and could influence poverty reduction. While COVID-19’s impacts on North American agriculture should have minimal effect on the Sustainable Development Goals (SDGs) through food prices, the ongoing global trends in trade and agribusiness accelerated by the pandemic are relevant for achievement of the SDGs.

1. Introduction

From the start of 2020 till the end of November 2020, over 62 million globally have contracted COVID-19 and over 1.5 million have died as a result of the virus. In addition to the direct human health impacts, governments have attempted to limit the spread of this infectious disease through restrictions on activities and interactions, thereby imposing additional costs. These restrictions have not impacted the primary agricultural sector to the same extent as other industries, as it has been deemed an essential service and has consequently been able to continue operating through the pandemic. However, COVID-19 caused direct and indirect disruptions to the farm sector after the immediate onset of the pandemic and will have long-term implications on the sector after the pandemic ends.

The purpose of this paper is to describe the short-term impacts and potential long-term implications of COVID-19 on the U.S. and Canadian farm sectors. The markets for agricultural commodities in these two countries are highly integrated, so the discussion of COVID-19's impacts will be by sector rather than by country. Farm sectors of focus include cattle, hogs, poultry, dairy, grains and oilseeds, and fruits and vegetables. For each sector, a team of experts was assembled with an attempt to obtain representation from the two countries and a mix of economists and production specialists.

The paper begins with an overview of the effects of COVID-19 common to all six commodities: (1) the shuttering of the hospitality sector with its subsequent impact on food demand and (2) the availability and health of workers in the supply chain. The short-term impacts of these effects are then discussed by commodity with year-over-year changes in inventories, trade and prices generally used to compare COVID-19 with "normal conditions." A common theme across all commodity evaluations is the growing importance of understanding the whole supply chain. Disruptions in the input markets (labour) and at the food service/retail sectors had implications for all other parts of the chain including the farm level. Although all sectors have rebounded relatively quickly, empty store shelves combined with the dumping of products implied a system lacking at least some degree of resiliency. The paper concludes by assessing the longer-term implications of the pandemic on the North American agri-food sector including means to enhance adaptability to future shocks.

2. Initial Effects of COVID-19 on the Agri-Food Supply Chain

Governments in the United States and Canada imposed stringent quarantine measures to "flatten the curve" and curtail the spread of COVID-19 beginning in the middle of March 2020. Businesses and

schools were closed and travel was restricted to local trips for essential services, resulting in a range of negative impacts on society (Leatherby and Gelles 2020). While the extent of the lockdown and its length varied across jurisdictions in both countries, the farm sector along with the whole agri-food supply chain was deemed to be an essential service, thereby allowing livestock to be raised, crops to be grown, and those goods to be transported to and from processing facilities unabated. In addition, given the limited contact between farm workers in many, but not all, commodities, it was relatively easy to abide by physical distancing restrictions. The lockdown did, however, cause significant disruptions in the food supply chain as consumers altered the amount and type of food they purchased and where they purchased it.

The short-term demand for food was affected in four significant ways through the closure of hotels, restaurants, schools and associated institutions. First, was an increase in sales volume at grocery stores. Since approximately half of the American and 35% of the Canadian consumer food dollar is spent on meals away from home (Saksena et al., 2018, Canning et al., 2016), the shuttering of the hospitality sector forced a reallocation of the food expenditures towards the food retail sector. Second, the type of food demanded shifted with the increase in purchases at grocery stores as well as the form and size of packaging. For example, North Americans generally eat more chicken wings and french fries in a food service setting than they do at home. Similarly, there are differences in the container sizes between the food sectors- milk is packaged in large bags or small creamers for food service while it is put into refrigerator-sized packaging for at home. A food item that was packaged in either small single serving sizes or industrial volumes for the hospitality sector was now required to be made in the size and form for sale in grocery stores. Third, there were some behavioural changes that affected demand. Many people started baking during the lockdown so the demand for flour and other baking ingredients went above what would have expected from a shift from food service to retail. Finally, there was also some stockpiling behaviour by consumers that drove short-term purchases, particularly for frozen food and meats, higher than would have been expected (Goddard, 2020).

Lean manufacturing and just-in-time production, distribution, and storage strategies have resulted in a low-cost food system, but the unusual and widely dispersed stresses of the pandemic economy revealed that this kind of system cannot respond easily or quickly to disruptions that are far outside the normal range. Some have described this as supply chains “being brittle.” The food supply chain tends to be characterized by plants that are specialized in their product lines, have a narrowly focused customer profile, and operate on production schedules based on well-known customer requirements. The sudden and dramatic shifts in the volume and form of food demanded by consumers

could not be met easily or quickly by those firms upstream. While processors needed time to adapt production and distribution schedules to the new demand scenario caused by COVID-19, production at the farm level had to continue due to the biological nature of production. This was particularly concerning for highly perishable products, such as milk on a daily basis, produce in a narrow window after it was ready for harvest, and meat animals who were at optimal market weight. Without sufficient buffer capacity in the system, there were well-publicized incidents of perishable products, such as farm milk and vegetables, being disposed of while systems adjusted. There were also cases of slaughter weight animals being euthanized for lack of processing options. Despite concerns about the inability of the North American agri-food sector to quickly adapt to the initial disruptions caused by COVID-19, by and large the agri-food supply chains adjusted and have by the end of 2020 largely returned to normal or near-normal operations, as will be outlined further for each commodity.

The ultimate concerns around COVID-19 center on its human health impacts. The disease does not discriminate, and workers in the agri-food supply chain are as susceptible to contracting the virus as anyone, and in some situations more so. Several large meatpacking facilities and a few dairy processing plants were forced to reduce operations or temporarily close because of an outbreak within their workforce and absenteeism issues. The bottleneck resulting from the temporary shutdown of these plants had ripple effects on livestock farmers upstream and food retailers downstream. Other parts of the supply chain found it difficult to obtain adequate labour as COVID-19 limited travel and restricted movement of foreign workers, including legally documented workers, that are key to the production of many farm goods such as fruits and vegetables. Even for those temporary foreign workers who were able to enter, infections were challenging to control given their close working and living arrangements. Whether it is in taking the precautions to try to keep workers healthy or dealing with workers who have become ill, the costs of production increased. The disruptions caused by workers contracting the virus and by the demand shifts prompted by policies designed to limit its spread are discussed by commodity in the following section.

3. Short-Term Impacts by Commodity

a. Cattle

The supply chain for the North American cattle sector is longer, more complex, and with less integration across sectors compared to other livestock commodities (see U.S. Government Accountability Office, 2018). Figure 1 illustrates these stages of the cattle supply chain and describes points in the supply chain where, to date, COVID-19 has had the greatest impacts. The direct impacts of COVID-19 on the cattle

supply chain have been largely restricted to the food service/grocery and meat packing sectors with surprisingly few other supply chain disruptions (i.e. wholesale/distribution, transport, feedlot, auction barns or feed mills). These direct impacts are first discussed followed by the subsequent impacts at the farm level of the supply chain, the feedlot and cow-calf operations.

The diversion of beef from the hospitality channel to grocery stores was not seamless because of differences in distributional logistics, package size and meat qualities. Reallocation of beef tended to discriminate against the most expensive restaurant cuts whereas individual grocery shoppers tended to purchase cheaper cuts and hamburgers. Early on, stock-outs (empty store shelves) at supermarkets occurred, but this affected frozen storable products more than fresh products. Some of the adjustment difficulties can be attributed to in-store logistical glitches, but also to a system built around just-in-time manufacturing and unexpected spikes in demand. Consumers practiced “forward buying” in anticipation of future restricted mobility and limited supplies. Meat shortages were minor, localized problems in the U.S. (e.g. hamburger shortages in Wendy’s) but were never a significant problem in Canada. These supply shortages were not a result of a shortage of animals, disruptions along the distribution network, or even hoarding behaviour, but rather due to labour shortages and physical shutdowns in the beef packing sector. Retail prices are derived from wholesale prices, so when wholesale prices doubled due to the supply constraints (see Figure 2) retail prices also increased but by a lower percentage (relative to early March prices rose 30% in the U.S. (BLS, 2020) and 10% in Canada (Statistics Canada, 2020)). Retail prices returned to pre-COVID-19 levels by June 2020.

The COVID-19 pandemic exposed the vulnerability of large North American regionalized beef packing plants. Across North America, a series of shutdowns and slowdowns stretching from late March to mid-June occurred as COVID-19 infected 9% of U.S. meat plant workers (Center for Disease Control, 2020). At the peak in late April, U.S. weekly beef production declined by one third (USDA AMS, 2020a). There are fewer Canadian plants (three plants produce 85% of the slaughter) and, as a result, domestic beef slaughter declined by over 60% at the peak (Canfax, 2020a; see Figure 3 for slaughter volumes in each country).

In the short run, feedlots were impacted by plant shutdowns and slower processing, and as a result, many farmers found that they had nowhere to deliver finished animals. The slaughter backlog led to reduced demand for fed cattle, resulting in a 30% lower price than the 5-year average in late April 2020 (LMIC, 2020a). Figure 4 illustrates the impact COVID-19 packer shutdowns had on fed cattle prices in the U.S. and Canada. In addition, feedlots faced higher input costs where: 1) rations had to be adjusted to hold cattle on feed and minimize weight gain until processing while being penalized for 6%

heavier than average slaughter weights (LMIC 2020b), and 2) feed prices increased for dry distillers' grains and other feed additives due to manufacturer shutdowns (both domestically and in China). These disruptions have since dissipated, as packing plants and feed manufacturers reopened in May.

While most meat processing facilities that had closed due to COVID-19 reopened, residual problems remain. These include: getting employees to return to work, anti-trust complaints against processors, producer complaints about backlogs, and numerous calls to reduce the vulnerability of the sector by re-introducing regionally dispersed small and medium packing plants. Health and safety changes resulted in slower processing line speeds and shifted production to high-volume, less processed cuts.

Adjustments across the cattle/beef supply chain are sequential and relatively slow in a sector where the chain is longer and more complex than other livestock supply chains. The complexity results from long biological lags, activities that are separated across agents, and production cycles that are spread over ten years. It takes time for the impacts of shocks in the retail and processing sectors to trickle down to the cow-calf sector. The price shock worked along the supply chain, resulting in small declines in feeder calf prices, and virtually no impact on cull cattle prices. In fact, cull cow prices have increased over 2019 values (but still lower than the 2014-2018 average) due to increased demand for lower-quality cuts, such as hamburger. How quickly these price declines are passed up the supply chain depends on the timing of the backlog of cattle yet to be slaughtered, when calves are placed in feedlots in autumn, and the breeding decision process as cow-calf producers respond to the negative shock. McKendree *et al.* (2019) established that ultimately, cow-calf producers are more impacted by price fluctuations than feedlot producers. Therefore, COVID-19 is likely going to have a more significant long-term impact on the prices that cow-calf producers receive.

b. Hogs

The United States and Canada have strong economic linkages and form part of an integrated North American pork industry (McEwan et al., 2020). Haley (2004) describes this integration in detail. Integration can provide for greater resiliency during major disruptions. However, the complementary system of production can also allow for adverse events to cascade from one country to another. The U.S. and Canadian pork industries' ability to adapt and begin the process of recovery from COVID-19 suggests it is the former. Yet, the experience to date provides a unique basis for evaluating the resiliency of the U.S. and Canadian pork industries.

The first shock to the market began in mid-March as the hospitality channel closed, the price U.S. and Canadian producers received for market hogs plummeted (Figure 5). As outbreaks temporarily closed plants in April and May, the second main shock, pork processing capacity became restricted and pork supply to retailers and consumers was reduced (Cowley, 2020). From mid-April through early May weekly hog slaughter in Canada fell as much as 17% below prior year levels while its six-fold larger counterpart, the United States, saw a drop of up to 35% (Figure 6). On April 28, 2020, U.S. President Donald Trump signed an executive order invoking the Defense Production Act, finding that processors of meat and poultry meet the criteria for essential infrastructure, and took all appropriate action to ensure continued operations (The White House, 2020). Pork processing arguably received much of the media attention leading up to and after this announcement.

As consumer purchasing shifted, retailers experienced tight supplies driving up wholesale pork prices and providing a small rebound in the price for hogs into May. Throughout the months that followed, the backlog of hogs for processing was one contributing factor that held prices low for producers. Just as there was considerable variability across U.S. prices, i.e., negotiated, other market formula, swine or pork market formula, and other purchase arrangements (data not shown), Canadian prices varied greatly by province. A majority of Canadian hogs are priced on a formula tied to a particular U.S. market or pricing structure (Grier, 2008; Ontario Pork, 2020), but new pricing systems based on wholesale pork cutout values are emerging in Canada (The Western Producer, 2020). The exchange rate is also a key part of the pricing formula in Canada because of the linkages to the U.S. market. By mid September market hog prices surpassed year earlier levels.

The consequences of the pandemic have been difficult for many producers across the United States and Canada. Through the first ten months of 2020, the estimated return to farrow-to-finish production shows 7-months of losses with the largest losses occurring in April, June, and July (Iowa State University, 2020). As of November 22, 2020, U.S. Department of Agriculture Coronavirus Food Assistance Program (CFAP) payments to U.S. hog producers who faced price declines and additional marketing costs due to COVID-19 totalled \$610.94 million (CFAP 1) and \$474.26 million (CFAP 2) (USDA 2020b, 2020c). The payments, however, did not cover the substantial losses incurred.

As market hog inventories rose and prices fell, producers tried to modify hog diets, adjust stocking densities, and find additional facility space to maintain pipeline hog supplies. However, the biological nature (i.e. gestation or finishing length) of hog production restricts producers from instantly responding to price changes. For example, the hogs weaned as COVID-19 events began to unfold in

February and March were part of the 11.8% and 12.8% greater year over year inventory of 120-179 pound and 80-pound and over market hogs on June 1, 2020, in the United States (USDA-NASS, 2020d).

As producers continue to make both short- and long-term decisions in managing their operations and inventories, it is important to recognize that economics will continue to drive the trajectory of the U.S. and Canadian swine herd. In the past when profits were low, producers cut sow herd numbers and left buildings empty, often depreciated, bringing them back into production for the next round of profits (Vansickle, 2006). However, due largely to the growth in the sector over recent years, there have been substantial investments in new and upgraded facilities across the supply chain, especially in the United States. Losses will not necessarily push producers to idle facilities. Producers lose less by maintaining full production, as long as expected prices cover variable costs and leave something to apply to fixed costs. And, there is also the risk return trade-off to consider. Producers who maintained capacities or bought feeder pigs at low prices in the spring and summer were well-positioned to make profits in the stronger market that ensued beginning in August 2020.

The highly integrated nature of the U.S. and Canadian pork industries allows for short-term impacts of the pandemic to be seen quite clearly by changes in live animal trade flows. The majority of imports from Canada are pigs under 50 kilograms contracted to U.S. finishers. Following the temporary processing delays and price drop, imports of Canadian hogs (<50kg) fell by 21% year-over-year on average in May with the greatest percentage reduction in 7-23 kg and 23-50 kg pigs. In June, a portion of these feeder pigs were exported to the United States at a heavier weight, as the “50 kg or more, other” category surged to almost a 1000% above year earlier levels. U.S. pig imports from Canada increased by 12% and 30% year-over-year for 7-23 kg and 23-50 kg hogs, respectively, in August, a signal of expected higher market hog prices and availability of finishing space and adequate slaughter capacity in the coming months.

While COVID-19 changed how and where pork consumption occurred and temporarily altered production and marketing, the supply of pork was relatively assured on balance in 2020 (USDA-WAOB, 2020; USDA-FAS, 2020). This assuredness of supply was a testament to the North American pork supply chain’s ability to adapt and adjust throughout the pandemic.

c. Poultry

The North American poultry industry predominantly has three types of domesticated birds: broilers, layers, and turkeys. Broilers are meat-type chickens and represent 70% of all poultry production value in the United States. These birds are harvested from four to eight weeks of age, with most at six weeks,

depending on the target market which ranges from retail ready-to-cook whole birds and parts to larger food service birds and further processing. Layers represent egg-type chickens which are typically white Leghorn or Rhode Island Reds depending on the desired shell colour. These eggs, called shell eggs at the farm, are diverted and sold as either table or breaker eggs. Breaker eggs are processed into a liquid, frozen, or dried eggs which are used in many food products. Turkeys are raised in sex-specific houses as toms are raised for a longer time (4-5 months) and to a heavier weight than hens (4 months) before harvest.

The U.S. poultry industry is characterized as a fully integrated system, where integrators retain ownership of birds and provide inputs such as feed, medicine, and technical assistance and producers provide management, facilities, land, and other production inputs like propane or water. Each of these inputs has individual integrator-owned breeding systems including primary breeders, hatcheries, and parent stocks. U.S. turkey production is very similar to broiler production in terms of housing and contracts.

In Canada, the poultry industry is based on a system of quotas held at the farm level. This supply management system provides stable cost of production-based returns to producers although it is often criticized for raising costs of poultry products at the consumer level. The marketing of poultry products is coordinated by provincial boards, which buy all of the farmers' products and sell it to processors. Hatcheries and breeding companies are independent although they coordinate with the provincial bodies.

The COVID-19 pandemic and the resulting poultry consumption disruptions created significant challenges for the broiler industry (Figures 7 and 8). The swift changes in poultry demand, driven by reduced food-service consumption, led to declines in poultry planned for production. Broiler chicks hatched in U.S. commercial hatcheries were 5.6 and 5.9 percent lower in April and May, respectively, than during the same months a year ago (USDA, NASS 2020e). The decreases for Canada were 4.3 percent and 11.3 percent for April and May respectively. This was a sharp contrast to the beginning of 2020 when broiler chicks hatched were 5.6 and 3 percent higher during January and February than during the first two months of 2019 for the U.S. and Canada, respectively. By June, U.S. hatching levels were only one percent below 2019 but Canadian levels were still down 8.4 percent.

In Canada, total chicken production was down 6 percent in May and 7 percent in June. Shifts in demand also exacerbated the disruption in the supply chain as the types of products demanded in retail and restaurant differ somewhat. Wing demand collapsed with restaurant closures reducing the return

per bird. The retail sector also generally wants smaller birds so some changes in production plans were also required.

At the processing level, COVID-19 led to shortages in the processing capacity due to labour shortages and additional cleaning and disinfection protocols. These impacts were worse in the U.S. than in Canada although there were some processing shutdowns due to COVID outbreaks. These shutdowns were usually short-lived. Processing capacity shortages led to birds being kept on feed for longer, which reduces production efficiencies, i.e., increases the cost per bird. These facilities went back online as soon as possible to minimize business disruptions, but any disruption upstream creates bottlenecks and issues downstream, especially in an integrated system like the poultry industry. In addition to supply chain impacts, COVID-19 also affected holiday demand due to smaller and reduced gatherings on average during the holiday season. However, with changes in poult placements, time to processing, and the integrated cold storage capacity, the turkey industry was able to manage the holiday demand in both the US and Canada.

Egg production was equally disrupted due to COVID-19. The typical diversion of shell eggs is around 70 percent table eggs and 30 percent processed eggs. During the outbreak, because of the limited processing and change in use, this diversion was modified with more eggs being sold as table eggs. For June 2020 there was a 10.2 percent reduction in breaker eggs compared to 2019 (USDA, AMS, 2020f). This number was 10.4 percent for Canada. Some breaker eggs that were not suitable for table egg sales were destroyed with no market or processing capacity for them, putting an additional financial strain on egg-producing firms. In Canada, these losses are spread across all producers through the supply management system. Some summer impacts are mitigated due to normal seasonal demand changes and reduced expectations during those times.

At the farm level, poultry growers experienced unique impacts that are difficult to accurately measure. The integrated structure of broiler and turkey production in the U.S. and supply management in Canada preclude the traditional price-risk impacts felt by producers of other commodities during the widespread market drops. Almost all U.S. poultry production is contracted to growers who do not have ownership of the birds. Instead, poultry growers face potential production shifts outside of their control that can lead to lower farm income. While production contracts specify the terms for grower compensation, poultry growers still face revenue risk. Detrimental changes in production attributes such as the number of days between flocks (i.e., out-time), the stocking density, or bird size can result in lower revenue even if the compensation structure remains stable. In terms of layer farms, these were slightly insulated from the same impacts as broilers as layers have a slower turn-over of birds, where the

typical laying flock is kept until the birds are 60 weeks old or longer. The reduced egg usage may have had implications for farm prices, but these rates are proprietary.

The farm-level impacts induced by the detrimental changes to production likely varied significantly across producers due to many factors. A grower's connection to processing plants that experienced a slowdown or shutdown was a key factor in how quickly birds were moved and replaced. In Canada, centrally coordinated sales may help to mitigate some of this risk for individual producers because losses are shared in the price pool. Additionally, the sales channels of a grower's integrator also had important implications for grower revenue. Companies commonly focus on retail outlets (e.g., restaurants, retail, international trade) and produce specialized bird sizes for those purchasers. Growers are often directly tied to a particular sales channel. Given the contrasting impact COVID-19 has had on restaurants vs. grocery stores, farm-level damages for U.S. producers could span from very little to severe, depending on the final consumer for an individual grower's production while in Canada those losses are pooled among all producers.

d. Dairy

As with poultry, the production of milk in Canada is controlled through a supply management system, which has implications on farm size and the extent of the disruptions caused by COVID-19. In 2019, there were 10,371 dairy farms in Canada with an average of 93 head per farm producing an average of 9,525 litres of milk per cow. In contrast, there were 34,187 dairy farms in the United States in the same year with an average of 273 cows per farm producing an average of 10,610 litres of milk. In both countries, dairy farms are owned and operated by families with limited backward vertical integration of the type seen in the U.S. poultry sector.

Single-desk selling of milk results in Canadian dairy farmers receiving a price based on a cost of production formula with adjustments for milk demand by processors of different categories of dairy products. The farm price for milk is a pooled or weighted average price based on all milk sold for dairy farmers in a province regardless of where an individual's milk is sold. Approximately three-quarters of milk in the United States is sold through marketing cooperatives, with a small but growing presence of farmers collaborating on marketing and processing activities through a Limited Liability Corporation (LLC). Through its Federal Milk Marketing Order system (and some much smaller but similar state-based programs) milk prices in the U.S. are regulated to ensure that 1) buyers of milk pay comparable prices for milk used to produce similar products and 2) farmers receive pooled milk values based on regional markets. Unlike the Canadian system, however, U.S. milk prices at the farm level are primarily

determined by market forces. U.S. milk prices cycle with a duration of approximately 3 years (Nicholson and Stephenson 2015), since the end of the Milk Price Support Program and the opening of trade in the 1990s.

Closures across the hospitality sector in the early months of the pandemic changed consumer demand for dairy products. Some products, heavily favoured in away-from-home food sales, saw large decreases. Other products more favoured in at-home consumption, saw increases. With a third of all dairy products purchased through the food-service sector, processors with limited retail access were forced to scale back. Overall demand for dairy products fell, with increased retail demand for household dairy products such as yogurt, butter, and fluid milk failing to out-weigh the drop in demand for cream and cheese products (USDA ERS, 2020g). When the government restrictions on foodservice were most widespread in April, domestic use dropped 6% in the U.S.

The different changes in milk production and prices for 2020 in the U.S. and Canada reflect the different marketing systems and the subsequent relative influence of COVID-19 as illustrated in Figure 9. Returns to U.S. dairy farms had been below average since 2014 but began to recover in the second half of 2019 with the expectation of continued strength through 2020. As a result, milk production grew briskly in the fourth quarter of 2019 and in January and February of 2020. However, the growth slowed in April and fell sharply in May due to changes in demand resulting from COVID. As was seen in other sectors, the retraction proved short-lived as milk production rebounded in June and July and is now increasing at the same annual rate as it was at the beginning of 2020. In contrast, farm milk prices in Canada remained relatively constant throughout 2020 (see Figure 8) as prices are established annually through negotiations between farmers and processors in the supply managed marketing system.

While the dairy supply chain has now adjusted to the disruptions caused by COVID, the initial onset resulted in milk dumping. Changes in the type of dairy products or in the packaging of the same product (i.e. reduction in small, single-use creamers or large volume bags of cream for coffee shops to containers of cream sold in grocery stores) require time to implement. However, raw, unpasteurized milk cannot be stored like other goods discussed previously. Without the buffer capacity to store milk that cannot be immediately processed, incidents of milk dumping occurred during early April in both countries.

The Canadian system with central selling and transportation coordination may have reduced the extent of dumping as compared to situations in the U.S. where dairy farmers were typically selling to a market cooperative for which processor demand was significantly reduced (Weersink et al., 2020). Yet dumping was far less prevalent than had been feared and was almost entirely restricted to early April.

Although specific data are not available nationwide, the Northeast market saw dumping spike to almost 6% of total raw milk production in April, but the months before and after were at normal levels.

Although other parts of the U.S. are not similarly documented, the Northeast has historically been the region most susceptible to dumping as a least-loss marketing strategy under demand duress, so 6% may have been the “worst case” estimate. Part of the adaption in the U.S. included processors, primarily cooperatively-owned, processing milk into storable products in hopes of a future sale rather than dumping it. U.S. stocks of cheese, butter, and nonfat dry milk spiked dramatically in April. Similarly, the Canadian Dairy Commission’s borrowing limit was increased by \$200 million allowing it to purchase and store excess butter and cheese (AAFC, 2020)

In an attempt to avoid over-supply to processors in Canada, over-quota shipments were penalized in some provinces from April to June. Despite the newly negotiated North American trade agreement, which increased market access to U.S dairy products, coming into effect on the first of July, many provinces outlined incentive days for the fall to increase short-term milk supply suggesting a return to pre-pandemic patterns.

Many U.S. dairy cooperatives also created or ramped up plans to discourage production increases or to distribute the costs of handling milk in excess of market demand. These plans have the common characteristic of establishing a two-tier pricing system. The first tier awards the prevailing market price to a certain base of production. The second tier is a punitive price designed to either discourage production beyond market needs or assign market losses on a pro rata basis to the “excess” production. Aggressive market coordination efforts by cooperatives and other processors to restrain growth or incentivize decreases likely played a key role in reducing production in April, but they were also easy to unwind when market demand rose. The fact that these plans are now “on the books” makes it easier to imagine implementing them again should market conditions again lead to severely depressed prices caused by a severe reduction in commercial sales. Non-cooperative processors who have an independent supply of milk do not have the option of two-tier pricing programs if they are regulated under a Federal Milk Marketing Order. With the vast majority of the U.S. milk supply marketed by cooperatives, the cooperative pricing plans represent a very effective restraint on national milk production.

e. Grains and Oilseeds

Grain and oilseed production occurs across North America and is concentrated in the U.S. Midwest or Cornbelt and the Canadian Prairies with significant production also across the Great Plains

and Delta regions of the U.S. and southwestern Ontario in Canada. For example, in 2019, 10 states contributed over $\frac{2}{3}$ the value of U.S. corn receipts¹ while 2 Canadian provinces and 5 U.S. states in the Central and Northern Great Plains produced more than 50% of wheat (USDA-NASS, 2019; STC and AAFC, 2019). Individual farms have relatively little market power and are generally price-takers. Since short-run demand and supply for grains and oilseeds are highly inelastic, prices are sensitive to exogenous shocks, particularly due to yield. In the longer run, supply response is associated with changes at the extensive margin in terms of land use rather than intensity (Roberts and Schlenker, 2013), while demand growth for these commodities largely depends on new uses (such as ethanol) and export markets.

The immediate market impacts of COVID-19 on the livestock sectors noted above had repercussions on the grain and oilseed markets. Moreover, COVID-19 distancing measures reduced travel, leading to declines in fuel use and subsequently also ethanol use. During the first three months of COVID-19 control measures, ethanol reductions reduced corn use by the equivalent of 741 million bushels (Irwin and Hubbs, 2020), or 5% of 2019 U.S. corn production.

COVID-19 immediately reduced grain demand because of the above-mentioned livestock and ethanol impacts. Corn was the most adversely impacted because of the dual impacts of reductions in livestock feed and ethanol demand. In 2018, 48% of corn was used in production feed and 38% was used in ethanol. As both these demands were high, harvest-time futures contracts fell by 17% from the first of March to mid-August 2020 (Schnitkey et al., 2020). By way of comparison, soybean prices fell 5% during the same time period. A much higher percentage of soybean use is in exports (44%), which was relatively less impacted by COVID-19. Grains that were less impacted by feed and ethanol demand had lower price declines. In 2018, only 4% of domestic wheat use was in feed, with the remainder in food use (50%) and exports (46%). Overall, wheat demand has been less impacted by COVID-19, and its responses have been muted (USDA-WASDE, 2020).

Overall, the impact of COVID-19 on grain and oilseed production was relatively muted relative to other sectors. In April 2020 there was extensive media coverage of the high demand for wheat flour for home baking. While some smaller mills saw a rapid increase in flour sales, the short-term surge in demand from home bakers was offset by decreased demand from restaurants and institutions and had no measurable impact on wheat supply or wheat prices received by producers (Bond, 2020; Figure 9). Consumer purchasing shifts, however, presented short-term challenges in packaging and distribution for the highly concentrated flour milling sector that is oriented more towards supplying food service,

¹ The ten states, in order of corn receipts are: Iowa, Illinois, Nebraska, Minnesota, Indiana, Kansas, South Dakota, Ohio, Missouri, and Wisconsin. (Economic Research Service, 2020b)

restaurants and institutional markets than smaller retail outlets. There was a reduction in the range of milled products offered in retail as millers scrambled to increase the volume into retail.

To counter COVID-19 control measures, the U.S. Department of Agriculture implemented CFAP, which in its first-round made payments to grain, livestock, and dairy producers (Paulson et al. 2020). In addition, many American farmers took advantage of broader programs to compensate firms for adverse financial results from COVID-19, including the Paycheck Protection Program (Lattz et.al. 2020) and the Economic Injury Disaster Loan (Swanson et al. 2020). These programs aided in mitigating income losses due to COVID-19. In contrast, no targeted financial assistance has been provided to Canadian farmers who will instead have to rely on existing business risk management programs such as AgriStability. The need for such support has fallen with the rise in crop prices since late summer as several events outside COVID-19 brightened the economic outlook.

f. Fruits and Vegetables

The production and distribution of fruits and vegetables in North America is a complex system that includes many individual firms and interconnected markets. The vast majority of the production of fruits and vegetables takes place on relatively large farms (MacDonald, Korb, and Hoppe 2013), and many of these farms integrate production, packing, and shipping activities. However, there are a non-trivial number of small- and medium-sized fruit and vegetable farms in North America that are an important source of supply, notably for niche products and urban markets. Because most of these small- and medium-sized farms distribute directly into either retail or food service channels, the fruit and vegetable supply system is considerably more fragmented than for dairy, meat, or eggs, for example. This fragmentation led to an initial sense that the industry lacked resilience, but it is also responsible for its rapid rebound.

There is a substantial level of integration between the fruit and vegetable sectors in the United States and Canada, as well as Mexico. In 2018 there were approximately 1.3 million hectares of fruit production in the United States, 0.9 million hectares in Canada, and another 2.0 million hectares in Mexico. For vegetables, production in the United States was approximately 1.0 million hectares, it was 0.7 million hectares in Mexico, and Canada produced another 0.1 million hectares. The total farm value of vegetables was approximately \$150 billion in each of the United States and Mexico in recent years. Firms produce fruits and vegetables in the three different countries at different times of the year, and a vast amount of trade occurs between the three countries. The majority of all internationally traded product by North American countries is sourced and delivered to other North American countries.

Normally an outgrowth, and benefit, of a well-integrated North American agricultural economy, this level of interaction between the U.S., Canada, and Mexico proved to be a source of additional problems during the COVID-19 crisis.

For fruit and vegetable markets, the effects of COVID-19 were not uniform across all individual fruit and vegetable items and varied depending on many factors including seasonality, international trade, convenience and ease-of-preparation considerations, fresh and processed products, and relative prices. After the initial disruption and concerns about the long-run implications on both demand and supply, fruit and vegetable prices and shipments have returned to levels observed in recent years, which will be illustrated further using a representative commodity, potatoes.

The differential influence of the coronavirus lockdown restriction on retail and food services can be shown with potatoes, broken out by region, in Figure 11. Arguably, the primary shock began in week 10 of the graphic, or March 10, 2020. Following this initial shock, the data show a rapid decline in potato shipments to food service, which are concentrated in Idaho shipping points. Colorado shipments, however, which are more concentrated on retail sales, saw a rapid increase. In the short-run, this rise in retail consumption of potato products did not offset the food service loss. By week 19 of the graphic (May 11, 2020), however, both the positive retail shock and negative foodservice shock had largely dissipated, and shipments returned to normal levels. This does not suggest that foodservice had returned to normal volumes, but rather shippers had found alternative ways of moving their output from foodservice to retail channels. Shippers were able to adapt and find new markets for their output, but a lack of resilience can be seen in the 7 to 9 weeks it took to find these new markets.

The North American network that supplies and distributes fruits and vegetables, similar to systems for many other food products, has been confronted with a number of challenges as a result of COVID-19. The first issue that has attracted much attention in the media and by industry leaders is the effect of the pandemic on the supply of farm workers given their importance in the fruit and vegetable industry. The initial concern was about finding a sufficient supply of labour in an era with increased border closures and limitations on travel. Later the concern shifted to the potential effects from an outbreak of the disease among workers in the field or in the processing and packing plants, similar to what was observed in the meat processing sector as discussed earlier. The impacts of COVID-19 on farm workers in the fruit and vegetable sector in 2020 has raised public awareness about the working and living conditions for these workers that will have long-term implications as discussed further below.

A second supply-side issue is coordinating production with a changing landscape of, and future uncertainty about, demand among food service and food retail consumers. Given that planting decisions

are typically made three to six months prior to harvest and distribution, many vegetable suppliers need to re-evaluate the optimal mix of crops to produce. Embedded in this decision is the effect that closed borders and reduced trade flows may have on imported quantities of fruits and vegetables. Additional concerns on the supply side relate to potential disruptions further downstream along the supply chain. Most notable among these concerns is the added costs that food distributors and food retailers will face in order to ensure safety for employees and consumers, and how this will affect the structure of those industries. These added costs coupled with a greater presence of on-line food sales may be particularly difficult for smaller independent food retailers that lack the resources needed to compete in this changing environment.

4. Longer-Term Implications Across Sectors

The previous section notes that, after the initial disruptions to consumer demand and labour supply caused by the outbreak of COVID-19, market prices and production levels for most farm commodities returned to levels observed in previous years. Yet, there are many concerns about the long-run implications on both consumer demand and product supply, and how markets will respond to a possible renewed flare-up of the disease or any other major market disruption. Any examination of longer-term impacts is by definition speculative and depends on factors such as the length of the pandemic, the severity of the recession, and changes in post-COVID-19 behaviour.

Agri-food supply chains in North America have become remarkably efficient, supplying an unprecedented variety of items at the lowest possible cost. However, the initial stages of the COVID-19 crisis and the near-total temporary loss of the foodservice distribution channel exposed a vulnerability that many found surprising. Growers and shippers who had either entirely committed to foodservice contracts, or had investments in packaging and distribution that were specific to the hospitality sector, were left with surpluses that had to be either discarded or donated to food banks (Kulish, 2020). The specialization of participants in the supply chain over time has lowered costs to consumers but limited reserve capacity to adapt to shocks such as the pandemic. The slow initial adaptation raised the issue of whether the food supply system needs to adjust so to enhance its resiliency in the long term.

Resilience is a difficult concept to define, and even researchers in the supply chain field struggle with a precise definition of what it takes for a particular supply chain to be resilient (Christopher and Peck, 2004; Ponomarov and Holcomb, 2009; Scholten, Scott, & Fynes 2014). Christopher and Peck (2004) note that there is a tradeoff between supply-chain efficiency and resilience, and define resilience in terms of an ability to react to shocks quickly, to observe shocks once they occur, and to be able to

increase the flow of product over a short time frame. However, their empirical examples are all from manufactured-goods industries, so they do not apply to agriculture as every production decision is subject to biological lags. Scholten, Scott, and Fynes (2014), on the other hand, maintain that resilience implies an ability to return to a former state following a shock. Although this definition may mirror the scientific definition of resilience as it applies to matter, it is less appropriate to a system that is as dynamic as the agri-food sector. As an alternative, Chenarides, Manfredo, and Richards (2020) define a resilient supply chain as one that is flexible, in the sense that shippers can move from one distribution channel to the other, without a loss of continuity, or lost output.

The slow adaptation displayed during the sudden shock from the pandemic can be explained by the concepts of hysteresis and the option value associated with the timing and form of investment. The current food supply chain involves a number of points of differentiation and specialization so that agents commit to another along that chain, such as a processor to either the hospitality or retail sector. Each point of differentiation tends to require fixed, irreversible investments in production or distribution but with uncertain returns to those investments. The decision to specialize or diversify into multiple products or buyers with greater costs involves a real option that can have significant value. The existence of real options means that producers, processors or shippers will “wait” to switch between channels in the supply chain so that assets become fixed in one aspect of the supply chain (Richards, 1996). Maintaining flexibility across production or distribution options generates real-option values, increasing the value of the firm to potential investors (Trigeorgis and Tsekrekos, 2018). Until now, those in the agri-food supply chain had not realized the value of these real options, so the least flexible were the most likely to fail.

Whether the agents along the food supply chain become smaller and more diverse depends ultimately on whether consumers reward businesses that make changes to increase their flexibility, paying more attention to “just-in-case” as opposed to “just-in-time”? Indeed, short of the next disruption, consumers will not likely know the measures businesses take to be resilient. Will they reward local businesses that shorten food miles along the entire supply chain even if it comes at a higher cost? As workers go back to work and children go back to school, will consumers resume eating patterns that put a premium on convenience and how quickly the task of eating is done, or will they savour the re-found joys of a home-cooked meal?

Given the extent of the initial disruptions, there is a push for increased meat packing through small and medium-sized plants because of perceived stress-time resilience. The calculus involved in making changes to the number, size, or design of facilities is complicated, and care should be taken to

appreciate the economic forces driving the industry's development to date. For example, a number of beef packing plants were built when Canadian cattle exports were stopped during BSE but many have subsequently closed because they were not economically viable. Ultimately a careful balance must be struck between efficiency and competitiveness in desired meat production during "normal times" with increased system resiliency during pandemics and other possible major disruptions (Tonsor and Schulz, 2020). Some jurisdictions have already indicated diversifying packing capacity as a policy priority. The Province of Ontario has announced funds to support expansion and addition of medium and small sized meat processors.

Regardless of the decision by individual components of the supply chain to increase reserve capacity, resiliency has been enhanced by increased collaboration as those components worked together to navigate the situation presented by COVID-19. Similar to crisis communication strategies, companies that spoke quickly and confidently gained worker and customer trust and had a much better basis for achieving mutual goals. The industry collective has developed additional protocols and best practices for improving the management of COVID-19 risks, such as personal protective equipment and staggered shift times, but more broadly, an entire industry may collectively implement more risk management plans. For example, one could argue that the North American pork industry is already better prepared to deal with major disruptions such as a foreign animal disease outbreak because of the lessons learned from the COVID-19 outbreak and subsequent impacts. The value of being prepared applies not only to the workplace but also to the market. For example, the pandemic spurred interest in the use of price risk management tools by farmers and processors in the U.S. dairy sector.

Risk management will also involve the acceleration of the automation process through the whole supply chain. The shutdown of a few meatpacking plants, through which much of the livestock in North America flow, caused significant disruptions to the meat supply chain. Going forward, aside from a COVID-19 vaccine, robotics offers the greatest potential to limit virus spread between workers while reducing floor space and waste, and producing a safe, more uniform product. However, the meat industry is not as conducive to robotics as other sectors and automation requires large financial investments with the slow payback requiring large volumes. In addition, primal beef cutting using robotics is a challenge due to wide variations in carcass size and shape. Unfortunately, current robots have both limited motion and decision-making ability to deal with this heterogeneity (Joshi et al., 2012).

The substitution of automated, robotic and intelligent machines for workers will also occur at the farm level, particularly for the fresh fruit and vegetable sector where harvesting is inherently labour-intensive and mechanization has been resisted for most commodities (Richards, 2018). COVID-19 crisis

has heightened the farm sector's awareness of the importance of being able to recruit and retain a consistent supply of productive, healthy, and well-trained workers. The H-2A program has allowed American farmers to increase the number of guest workers from around 48,000 in 2005 to over 240,000 in 2018 (U.S. Department of Labor). During the early days of the COVID-19 crisis, there was a deep concern that growers would not be able to recruit workers from foreign labour markets but these concerns have not materialized (Chenarides, Manfredo, and Richards, 2020). Similarly, in Canada, accommodations were made to ensure the supply of temporary foreign workers continued. Longer-term, however, farmers in all sectors remain concerned that there is no permanent solution to labour-shortage problems from either foreign or domestic sources that increasingly plague the industry.

In addition to the movement to labour-saving technology, another long-term structural change in the sector may be greater industry concentration through the accelerating of current trends towards consolidation throughout the supply chain. Because the demand for most foods is relatively constant, the failure of too many firms in the supply chain will inevitably lead to increased concentration. Even prior to the COVID-19 pandemic, farmers had access to fewer and fewer buyers as mergers and acquisitions, in search of economies of scale, led to concerns regarding buyer power. Fruit and vegetable markets, in general, are unique among industries in North America in the relative importance of "oligopsony power" in driving down market prices, compared to "oligopoly power" that tends to raise consumer prices further down the supply chain. Essentially, there are thousands of small sellers in many regions of the country, but only a few large buyers, so the buyers can force wholesale prices down. If business-failures among produce buyers caused by the COVID-19 crisis lead to even fewer buyers, farm prices for many fresh produce items may be forced down over time, making matters worse for growers upstream, and consumers downstream as these sellers raise prices to retail customers.

At one time, economists believed that the move to online purchasing would alleviate concerns over retail market power. That is, if "transaction costs," or the cost of searching for products in a physical store prevent retail food markets from being perfectly competitive, then reducing these costs online would have to improve the competitiveness of all retail food markets. In fact, many predicted the "commoditization" of retail food markets as online shopping would ensure that the ability to compare prices from different vendors in a low-cost way would drive retail food prices down. However, the opposite is more likely the case. Rather than cause foods to become commodities, lower search costs lead consumers to search for exactly the item they want, increasing the price-premium for hyper-differentiation, and raising the return to retailers who are able to hold large inventories. This "retail long-tail" effect (Anderson, 2006) has been well-documented in categories like books, movies, and other

electronic items, but the same effect is true for online foods (Richards, Hamilton, and Empen 2017). This may also be the reason why Amazon bought Whole Foods in June 2017 – to replicate in fresh foods the long-tail strategy that had been so successful in other categories. On the other hand, smaller processors who provide direct to consumer offerings may be able capture a portion of these hyperdifferentiated markets if they are able to identify and connect with the specific consumer.

The COVID-19 pandemic will have long-term impacts on farm policy in the United States and perhaps in Canada if there is pressure to match the level of support received by American farmers. Government payments under MPF and CFAP in the U.S. now dwarf other farm program payments that are intended to address production and market risk, including crop insurance subsidies. Payments related to COVID-19 are projected to be responsible for a 66% increase in government payments in 2020, while total government payments are projected to make up nearly a third of net cash farm income (USDA-ERS, 2020h). The magnitude and politicization of these payments have raised concerns about the stability of farm policy in future (McCrimmon, 2020). Supplemental and ad hoc payments by nature are difficult to predict and subject to the current political environment. Uncertainty about the level of government support for agriculture and related policy debates will have a large role in U.S. grain and oilseed production over the coming decade.

The largest immediate impacts of COVID-19 stemmed from the changes in consumer demand driven by either forced closures of the hospitality channel or the reduction in purchasing power from those losing jobs. The longer-term impact on food consumption depends on income effects. This year the International Monetary Fund (IMF) is predicting an 8% decline in Advanced Economy Gross Domestic Product (GDP), and it is anticipated that the recession will be long and deep (IMF, 2020). Pandemics or recessions have the capacity to decrease nutritional intake and dietary quality if consumers resort to more calorie-dense “comfort” foods. However, other surrounding conditions and an increase in time spent planning and preparing meals may lead to an increase in overall dietary quality as found by Todd and Morrison (2014) in the Great Recession of 2008. In addition, if we see sustained changes in relative food prices or in household income, we may see non-trivial substitution patterns between food categories and potential changes in food consumption (Richards and Rickard, 2020). For example, a long-term economic downturn is more likely to affect the goods with an income elasticity greater than one, such as red meat. Whatever the changes in food consumption and thus farm price, the adaptation will occur over a longer period of time than the shock associated with the initial onset of the pandemic.

During a pandemic or a recession, consumers may be less interested in certain credence attributes such as how the food was grown (i.e. organic) or where (i.e. local) (Cranfield, 2020). However,

consumer behaviour may also change in favour of local food if they view these sources of supply to be more resilient in uncertain markets (Hobbs, 2020). The potential change in the food supply chain to a more local and more resilient system depends ultimately on whether consumers are willing to pay for this credence attribute.

5. Sustainable Development Goals and COVID-19

As it relates to the Sustainable Development Goals (SDG) of the United Nations, the North American agri-food supply chains are ideally suited to consider the economic trade-offs between innovation, competing resiliency efforts, and efficiency. These markets faced adaptation difficulties in the short run following the outbreak of the disease, but have shown a surprising level of stability over a longer time horizon. There is a new understanding of the ability to cope with risks that are unpredictable, sudden, and national or international in scope.

The most direct effect of agricultural production in the U.S. and Canada on the SDGs is through food prices. While some food prices have increased and supply chains have been disrupted (Reardon et al., 2020), there largely have not been widespread declines in affordable food in response to COVID-19 (World Bank, 2020). However, issues with food availability, access, utilization and stability are still of concern for global food security (Laborde et al., 2020). Barrett (2020) argues that the negative impacts of COVID-19 on food systems are most effectively addressed through demand-side policies.

In the long term, COVID-19 impacts on global commerce and developing country production are more uncertain and could influence poverty reduction (Cardwell and Ghazalian, 2020). The shift of the U.S. towards a more mercantile and protectionist approach to trade (Nelson, 2019), as well as a shift to bilateral and regional trade agreements (Noland, 2018), may lead to a weakening influence of the WTO and more agricultural protectionism. Indeed, although the U.S. shift predates the pandemic and may change with the election result, many countries became more nationalistic in their public health and economic responses to the pandemic. To the degree that this leads to less market access for developing country producers, it could limit in the rate of poverty reduction. On the other hand, more political attention to groups that do not benefit from trade could in the long-term lead to more stable, robust gains in international commerce. In short, COVID-19 impacts on North American agriculture should have minimal effect on the SDGs through food prices, but ongoing global trends in trade and agribusiness accelerated by the pandemic are relevant for the achievement of the SDGs.

6. Conclusions

The greatest immediate impact of the COVID-19 pandemic on the North American agricultural sector stemmed from the near complete closure of the hospitality channel and the subsequent realignment of the supply chain. Demand shifted away from food service to food retail, but the systems that have evolved to deliver food at the lowest cost to these end users could not adapt quickly enough to such a large shock. The disruptions were compounded by consumers' panic buying and by workers in the supply chain becoming infected with the virus and forcing temporary constrictions in the flows of goods. During the first month of the pandemic, images of milk dumping and crops rotting suggested the agri-food supply chains lacked resilience and disruptions would continue through the summer.

Instead of continued shortages, the agri-food sector has since moved back to near normal conditions with prices and production levels similar to those typically observed in previous years prior to the pandemic within a few months. The U.S.-Canada border has been closed to non-essential traffic since mid-March, but agricultural trade between the two countries did not fall (USDA 2020). Ironically, the specialization and fragmentation for most food supply chains designed for "just-in-time" delivery with no reserve capacity that led to the initial disruptions may have also been responsible for its rapid rebound.

Over the longer term, a continuation of the pandemic could push the supply chain toward greater consolidation and diversification given the increasing option value of maintaining flexibility. Other structural changes will be felt through input markets, most notably labour, as the trend toward greater automation will continue to accelerate as a response to meeting concerns about a consistent supply of healthy and productive workers. The economic fall out of the pandemic may include a greater concentration in the sector as some firms are not able to survive the downturn. It may also induce changes in consumer food buying behaviour ranging from more online shopping to enhanced demand for attributes associated with increasing the resiliency of the food system, such as increasing purchases from local suppliers. A better understanding of the potential long-term impacts requires more research into the economics of the complete agri-food supply chains, particularly during disasters, rather than just portions of the chain (Zilberman, Liu and Reardon, 2019).

References

- Anderson, C. (2006). *The long tail: Why the future of business is selling less of more*. Hachette Books
- Agriculture and Agri-Food Canada (2020, May 15). *Helping the dairy sector mitigate the impact of COVID-19* [Press release]. Retrieved from <https://www.canada.ca/en/agriculture-agri-food/news/2020/05/helping-the-dairy-sector-mitigate-the-impact-of-covid-19.html>
- Barrett, C. B. (2020). Actions now can curb food systems fallout from COVID-19. *Nature Food*, 1-2.
- BLS, 2020, "Average Retail Food and Energy Prices, U.S. and Midwest Region - Beef and veal" U.S. Bureau of Labor Statistics https://www.bls.gov/regions/mid-atlantic/data/averageretailfoodandenergyprices_usandmidwest_table.htm
- Bond, J K., *Wheat Outlook*, WHS-20e, U.S. Department of Agriculture, Economic Research Service, May 14, 2020.
- Canfax, 2020a , "Canadian Weekly AAA Cut-out Values, " Personal Communication <http://www.canfax.ca/Main.aspx>
- Canfax, 2020b , "Weekly Canadian Federally Inspected Slaughter Data" Personal Communication <http://www.canfax.ca/Main.aspx>
- Canfax, 2020c, "Alberta Weekly Fed Steer Price," Personal Communication <http://www.canfax.ca/Main.aspx>
- Canning, P., Weersink, A., & Kelly, J. 2016. Farm share of the food dollar: an IO approach for the United States and Canada. *Agricultural Economics*, 47(5), 505-512
- Cardwell, R. and Ghazalian, P.L. (2020). Covid-19 and international food assistance: Policy proposals to keep food flowing. *World Development*, 135, Article 105059.
- Centers for Disease Control, 2020. Update: COVID-19 Among Workers in Meat and Poultry Processing Facilities — United States, April–May 2020. Centers for Disease Control and Prevention. <https://www.cdc.gov/mmwr/volumes/69/wr/mm6927e2.htm> (accessed July 30, 2020).
- Chenarides, L., Manfredo, M., & Richards, T.J. 2020. Covid-19 and food supply chains. *Applied Economic Perspectives and Policy*. Forthcoming.
- Christopher, M., & Peck, H. 2004. Building the resilient supply chain. *International Journal of Logistics Management*, 15(2), 1-13.
- Cowley, C. 2020. COVID-19 disruptions in the U.S. meat supply chain. Federal Reserve Bank of Kansas City. <https://kansascityfed.org/research/regionaleconomy/articles/covid-19-us-meat-supply-chain?sm=rs080320>.
- Cranfield, J.A.L. 2020. Framing consumer demand responses in a viral pandemic. *Canadian Journal of Agricultural Economics* 68(2): 151–156.
- Deaton, B. J., & Deaton, B. J. (2020). Food security and Canada's agricultural system challenged by COVID-19. *Canadian Journal of Agricultural Economics*. 68(2), 143-149
- Goddard, E., 2020. The Impact of COVID-19 on Food Retail and Food Service in Canada: Preliminary Assessment. *Canadian Journal of Agricultural Economics*. 68(2), 157-161. <https://doi-org.proxy1.cl.msu.edu/10.1111/cjag.12243>
- Grier, K. 2008. Perfect Storm Converges On Struggling Industry. *National Hog Farmer*. January 15. https://www.nationalhogfarmer.com/marketing/struggling_canadian_pork_industry.
- Haley, M.M. Market Integration in the North American Hog Industries. Electronic Outlook Report from the Economic Research Service. United States Department of Agriculture. LDP-M-125-01. November 2004.
- Hobbs, J.E, 2020. Food supply chains during the COVID-19 pandemic. *Canadian Journal of Agricultural Economics*. 68: 171– 176. <https://doi-org.proxy1.cl.msu.edu/10.1111/cjag.12237>

- International Monetary Fund (IMF), 2020. World Economic Outlook Update, June 2020. <https://www.imf.org/en/Publications/WEO/Issues/2020/06/24/WEOUpdateJune2020> (accessed July 30, 2020)
- Iowa State University. 2020. Estimated Livestock Returns. <http://www2.econ.iastate.edu/estimated-returns/> (accessed November 24, 2020)
- Irwin, S. and T. Hubbs. 2020. The Coronavirus and Ethanol Demand Destruction. *farmdoc daily* (10):56 Dept of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, March 26.
- Joshi K., T. Norton, J. Frías, and B. Tiwari, 2012. Robotics in meat processing. Emerging Technologies in Meat Processing: Production, Processing and Technology (E. Cummins and J. Lyng, editors) John Wiley & Sons, Ltd.
- Kulish, N. 2020. 'Never Seen Anything Like It': Cars Line Up for Miles at Food Banks. *New York Times*. Available at: <https://www.nytimes.com/2020/04/08/business/economy/coronavirus-food-banks.html>
- Laborde, D., Martin, W., Swinnen, J., & Vos, R. (2020). COVID-19 risks to global food security. *Science*, 369(6503), 500-502.
- Lattz, D., B. Rhea, G. Schnitkey, K. Swanson, N. Paulson and J. Coppess. "The Paycheck Protection Program (PPP) of the CARES Act." *farmdoc daily* (10):69, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, April 14, 2020.
- Leatherby, L., and D. Gelles. 2020. How the Virus Transformed the Way Americans Spend Their Money. *New York Times*. Available at: <https://www.nytimes.com/interactive/2020/04/11/business/economy/coronavirus-us-economy-spending.html>. Accessed on July 14, 2020.
- Livestock Marketing Information Center (LMIC), 2020a. Weekly Cattle Prices PowerPoint. imic.info. Accessed July 22, 2020.
- Livestock Marketing Information Center (LMIC), 2020b. Weekly Cattle Slaughter PowerPoint. imic.info. Accessed July 22, 2020.
- MacDonald, J.M., P. Korb, and R.A. Hoppe. 2013. Farm size and the organization of U.S. crop farming. USDA-ERS Economic Research Report Number 152. Available at: https://www.ers.usda.gov/webdocs/publications/45108/39359_err152.pdf
- McCrimmon, R. (2020). 'Here's your check': Trump's massive payouts to farmers will be hard to pull back. *Politico*. Available <https://www.politico.com/news/2020/07/14/donald-trump-coronavirus-farmer-bailouts-359932>
- McEwan, K., Marchand, L., Shang, M., & Bucknell, D. 2020. Potential implications of Covid-19 on the Canadian pork industry. *Canadian Journal of Agricultural Economics*, 68: 201–206.
- McKendree, M.G.S., G.T. Tonsor, T.C. Schroeder, and N.P. Hendricks, 2019. Impacts of retail and export demand on United States cattle producers. *American Journal of Agricultural Economics*. 102(3), 866-883. <https://doi-org.proxy1.cl.msu.edu/10.1093/ajae/aaz034>
- Nelson, D. R. (2019). Facing up to Trump administration mercantilism: The 2018 WTO trade policy review of the United States. *The World Economy*, 42(12), 3430-3437.
- Noland, M. (2018). US trade policy in the Trump administration. *Asian Economic Policy Review*, 13(2), 262-278.
- Nicholson, C. F. and M. W. Stephenson. 2015. Price Cycles in the U.S. Dairy Supply Chain and their Management Implications. *Agribusiness: An International Journal*, 31:507-520. DOI: 10.1002/agr.21416
- Ontario Pork. 2020. Price Calculation. <https://www.ontariopork.on.ca/Price-Reporting/Price-Calculation>.

- Paulson, N., G. Schnitkey, J. Coppess, C. Zulauf and K. Swanson. "Coronavirus Food Assistance Program (CFAP) Rules Announced." *farmdoc daily* (10):95, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, May 22, 2020.
- Ponomarov, S. Y., & Holcomb, M. C. 2009. Understanding the concept of supply chain resilience. *International Journal of Logistics Management*, 20(1), 124-143.
- Reardon, T., Bellemare, M. F., & Zilberman, D. 2020. How COVID-19 may disrupt food supply chains in developing countries. in *Covid-19 and Global Food Security*, chapter 17, pages 78-80, International Food Policy Research Institute (IFPRI)
- Richards, T. J., 1996. Economic hysteresis and the effects of output regulation. *Journal of Agricultural and Resource Economics*, 21(1): 1-17.
- Richards, T. J. 2018. Immigration reform and farm labor markets. *American Journal of Agricultural Economics*, 100(4), 1050-1071.
- Richards, T.J., S.F. Hamilton, and J. Empen. 2017. Attribute Search in Online Retailing. *American Journal of Agricultural Economics* 99(1): 1- 18.
- Richards, T.J., and B.J. Rickard. 2020. COVID-19 Impact on Fruit and Vegetable markets. *Canadian Journal of Agricultural Economics* 68(2): 189–194.
- Roberts, M. J., & Schlenker, W. 2013. Identifying supply and demand elasticities of agricultural commodities: Implications for the US ethanol mandate. *American Economic Review*, 103(6), 2265-95.
- Saksena, M.J., Okrent, A.M., Anekwe, T.D., Cho, C., Dicken, C., Effland, A., Elitzak, H., Guthrie, J., Hamrick, K.S., Hyman, J. and Jo, Y., 2018. *America's Eating Habits: Food Away From Home* (No. 281119). United States Department of Agriculture, Economic Research Service
- Schnitkey, G., K. Swanson, N. Paulson, J. Coppess and C. Zulauf. 2020. "Corn and Soybean Price Changes and Relative Profitability." *farmdoc daily* (10):179, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, October 6.
- Scholten, K., Scott, P. S., & Fynes, B. 2014. Mitigation processes--antecedents for building supply chain resilience. *Supply Chain Management: An International Journal*, 19(2), 211-228.
- Statistics Canada, 2020. Monthly average retail prices for food and other selected products. <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1810000201> (accessed July 30, 2020)
- Swanson, K., G. Schnitkey, N. Paulson, J. Coppess and C. Zulauf. 2020. Pandemic Relief Update: Economic Injury Disaster Loan Program. *farmdoc daily* (10):87, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, May 12.
- The Western Producer. 2020. U.S.-based hog prices part of problem: report. July 30. <https://www.producer.com/2020/07/u-s-based-hog-prices-part-of-problem-report/>.
- The White House. 2020. Executive Order on Delegating Authority Under the DPA with Respect to Food Supply Chain Resources During the National Emergency Caused by the Outbreak of COVID-19. April 28. <https://www.whitehouse.gov/presidential-actions/executive-order-delegating-authority-dpa-respect-food-supply-chain-resources-national-emergency-caused-outbreak-covid-19/>.
- Todd, J., and R.M. Morrison. 2014. Less Eating Out, Improved Diets, and More Family Meals in the Wake of the Great Recession. *Amber Waves* 2(March). USDA, ERS.
- Tonsor, G. and L. Schulz. 2020. COVID-19 Impacts on the Meat Processing Sector. CAST Commentary: Economic Impacts of COVID-19 on Food and Agricultural Markets. QTA2020-3. June 29. <https://www.cast-science.org/wp-content/uploads/2020/06/QTA2020-3-COVID-Impacts.pdf>.
- Trigeorgis, L., & Tsekrekos, A. E. 2018. Real options in operations research: A review. *European Journal of Operational Research*, 270(1), 1-24.

- U.S. Department of Agriculture, Agricultural Marketing Service (USDA-AMS), 2020a. National Weekly Cattle and Beef Summary. USDA Livestock, Poultry & Grain Market News. <https://www.ams.usda.gov/mnreports/lswwcbs.pdf> (accessed July 27, 2020).
- U.S. Department of Agriculture (USDA). 2020b. Coronavirus Food Assistance Program 1 Data. <https://www.farmers.gov/cfap1/data>.
- U.S. Department of Agriculture (USDA). 2020c. Coronavirus Food Assistance Program 2 Data. <https://www.farmers.gov/cfap/data>.
- U.S. Department of Agriculture, National Agricultural Statistics Service (USDA-NASS). 2020d. United States and Canadian Hogs. August 25. <https://downloads.usda.library.cornell.edu/usda-esmis/files/7h149p85x/7s75f228k/73666s37b/usch0820.pdf>.
- U.S. Department of Agriculture, National Agricultural Statistics Service (USDA-NASS). 2020e. "Chickens and Eggs." ISSN: 1948-9064. Various issues. Available online <https://downloads.usda.library.cornell.edu/usda-esmis/files/fb494842n/c534g934p/kw52jx685/ckeg0720.pdf>
- U.S. Department of Agriculture, Agricultural Marketing Service (USDA-AMS). 2020f. "Egg Market News Report." ISSN: 1520-6122. 67(29). Available online <https://www.ams.usda.gov/mnreports/pybshellegg.pdf>
- U.S. Department of Agriculture, Economic Research Service (USDA-ERS), 2020g. Dairy Data. <https://www.ers.usda.gov/data-products/dairy-data/>
- U.S. Department of Agriculture, Economic Research Service (USDA-ERS), 2020h. Farm Income and Wealth Statistics. <https://www.ers.usda.gov/data-products/farm-income-and-wealth-statistics/data-files-us-and-state-level-farm-income-and-wealth-statistics/> (accessed November 20, 2020)
- U.S. Department of Agriculture, Economic Research Service (USDA-ERS), 2020a. Archived food expenditure tables. Food Expenditure Series. <https://www.ers.usda.gov/data-products/food-expenditure-series/> (accessed July 30, 2020)
- U.S. Department of Agriculture, Foreign Agricultural Service (USDA-FAS). 2020. Livestock and Poultry: World Markets and Trade. Various months. <https://usda.library.cornell.edu/concern/publications/73666448x?locale=en> (accessed November 24, 2020)
- U.S. Department of Agriculture, Agricultural Marketing Service (USDA-AMS), 2020c. Market News Report, Specialty Crops. <https://www.ams.usda.gov/market-news/fruits-vegetables> (accessed June 1, 2020).
- U.S. Government Accountability Office, 2018. Additional Data Analysis Could Enhance Monitoring of U.S. Cattle Market. No. GAO-18-296, U.S. Department of Agriculture. Available at: <https://www.gao.gov/assets/700/691178.pdf> (accessed July 29, 2020).
- U.S. Department of Agriculture, World Agricultural Outlook Board (USDA-WAOB). 2020. WASDE Report. Various months. <https://www.usda.gov/oce/commodity/wasde> (accessed November 24, 2020).
- U. S. Department of Labor (2020). Performance data. (<https://www.dol.gov/agencies/eta/foreign-labor/performance>). Accessed June 1, 2020.
- Vansickle, J. 2006. Three-Peat Projected for Hog Profits. National Hog Farmer. March 15. https://www.nationalhogfarmer.com/mag/farming_threepeat_projected_hog.
- World Bank. (2020) Food Security and COVID-19. Brief 14 Sept 2020. Available: <https://www.worldbank.org/en/topic/agriculture/brief/food-security-and-covid-19>.
- Weersink, A., von Massow, M., & McDougall, B. (2020). Economic thoughts on the potential implications of COVID-19 on the Canadian dairy and poultry sectors. *Canadian Journal of Agricultural Economics*. 68(2): 195-200.

Zilberman, D., Lu, L., & Reardon, T. (2019). Innovation-induced food supply chain design. *Food Policy*, 83, 289-297.

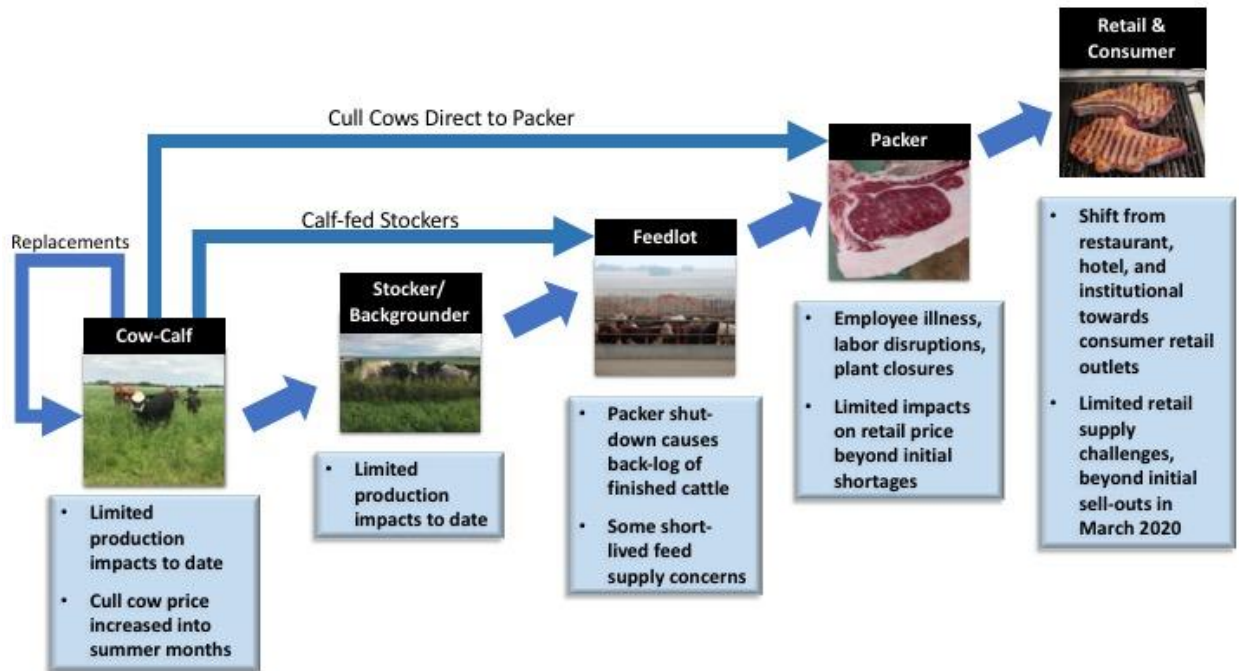
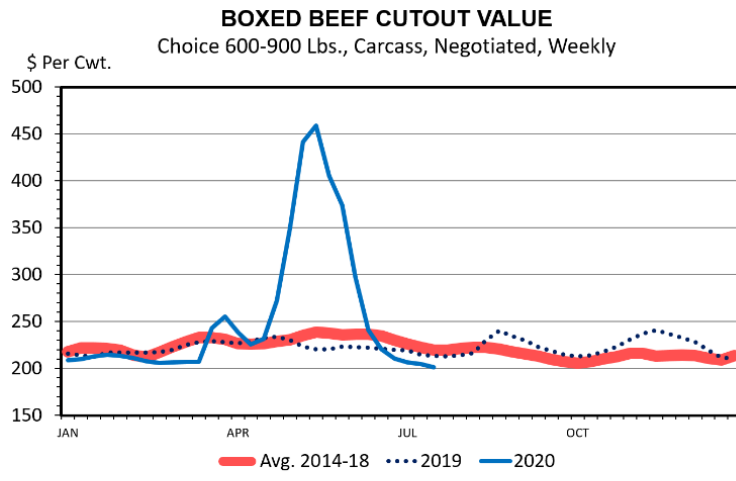


Figure 1: Beef cattle supply chain and a summary of the impacts on COVID19 on each sector

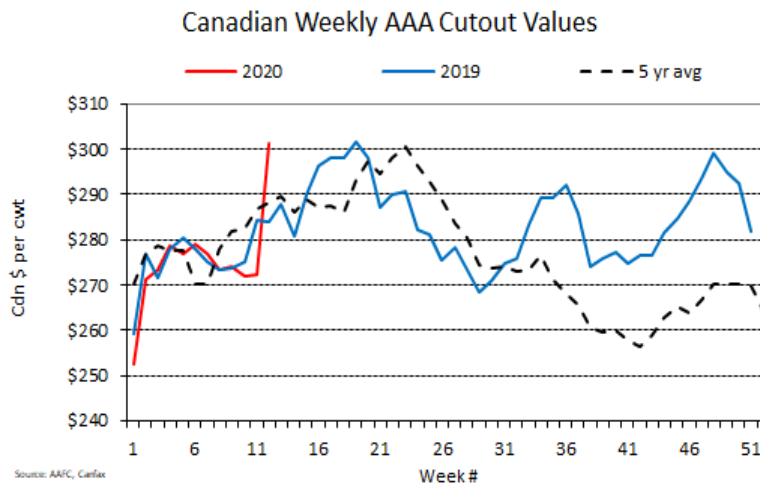


Data Source: USDA-AMS
Livestock Marketing Information Center

C-P-62
07/20/20

Figure 2:
prices for
United
2019, 2020

Sources: panel
Marketing
(LMIC, 2020a)
USDA-AMS;
(2020b)



Source: AAFC, Canfax

Weekly wholesale
boxed beef for
States and Canada,
and 5 year average
(a) by the Livestock
Information Center
with data from the
panel (b) from Canfax
Personal

Communication

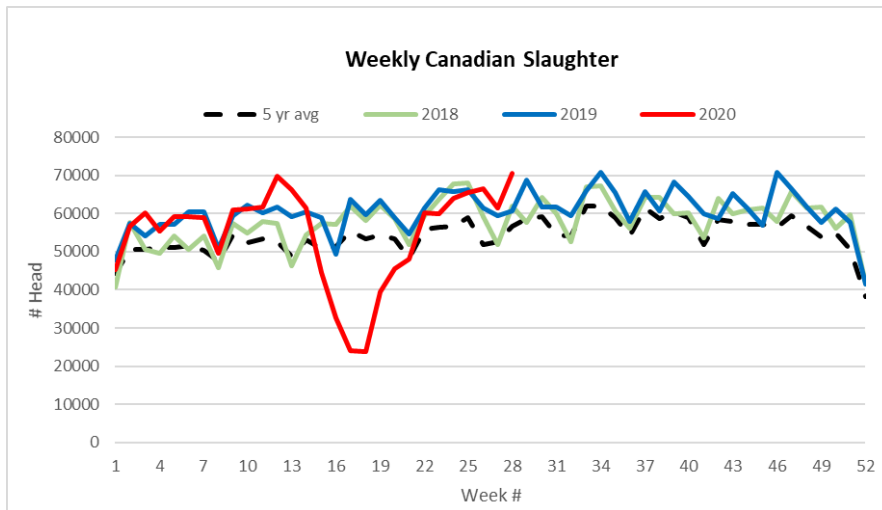
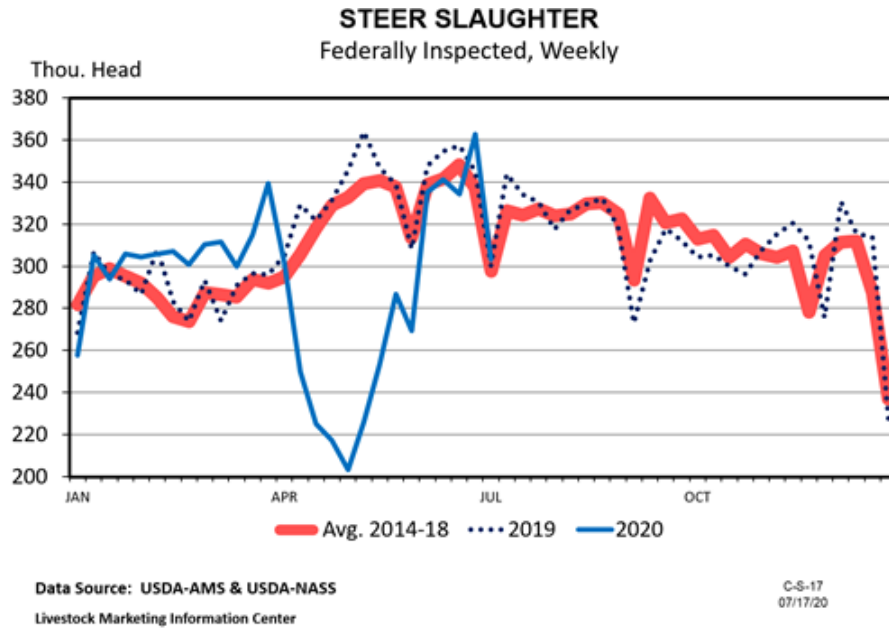


Figure 3: Weekly steer slaughter in United States and Canada, 2019, 2020 and 5 year average

Sources: panel (a) by the Livestock Marketing Information Center (LMIC, 2020b) with data from the USDA-AMS and USDA-NASS; panel (b) from Canfax (2020a) Personal Communication

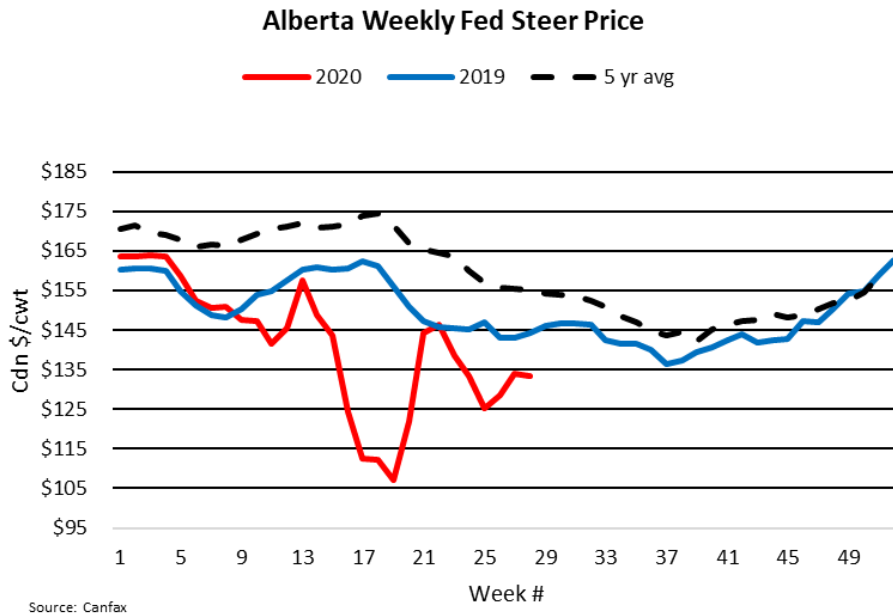
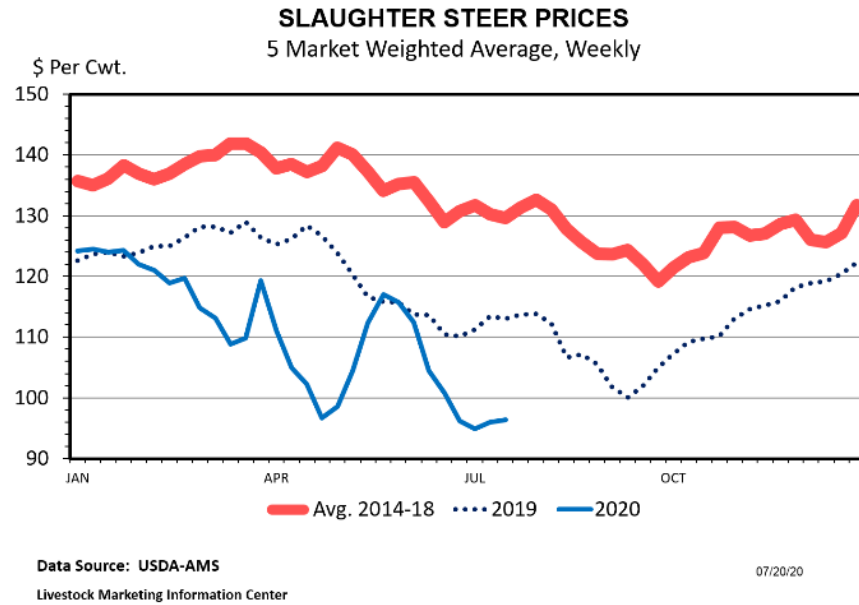


Figure 4. Weekly fed steer price on the United States and Canada, 2019, 2020 and 5 year average

Sources: panel (a) by the Livestock Marketing Information Center (LMIC, 2020a) with data from the USDA-AMS and USDA-NASS; panel (b) from Canfax (2020c) Personal Communication

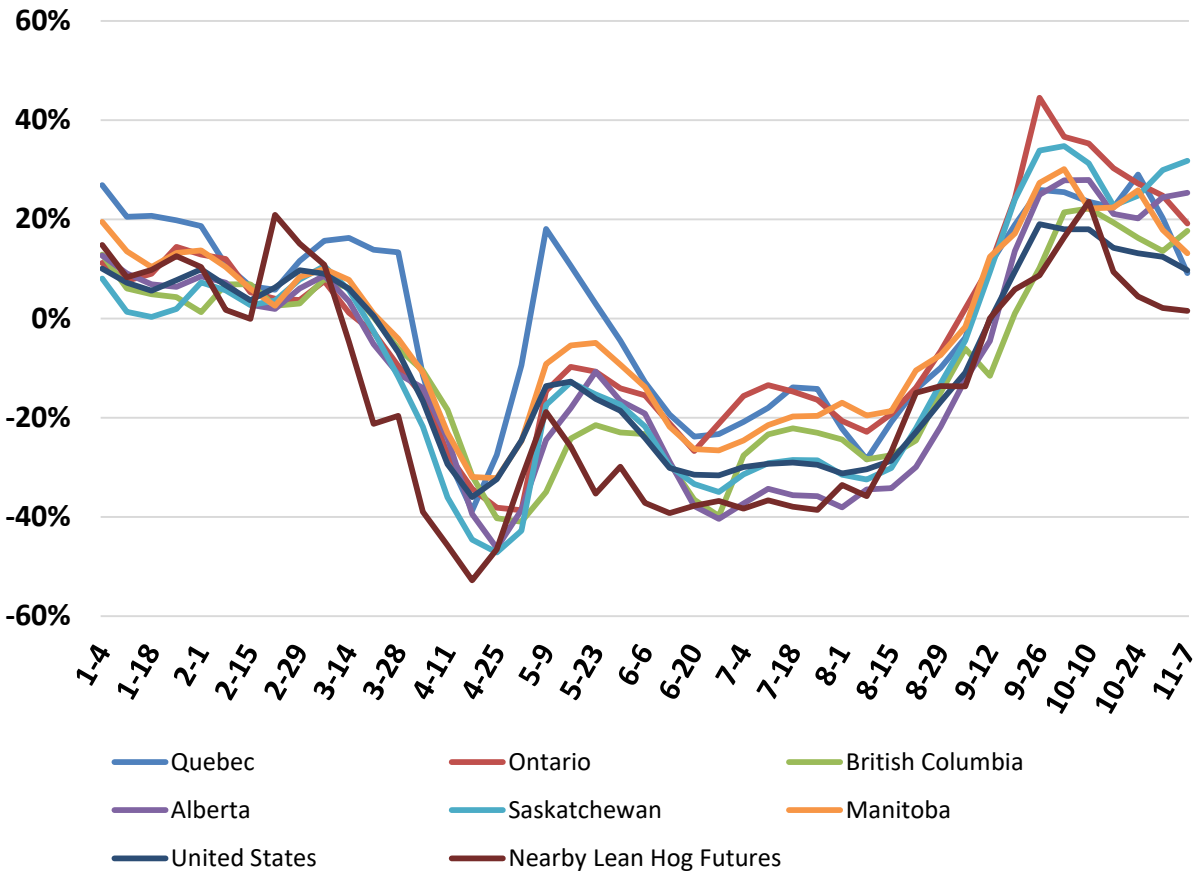
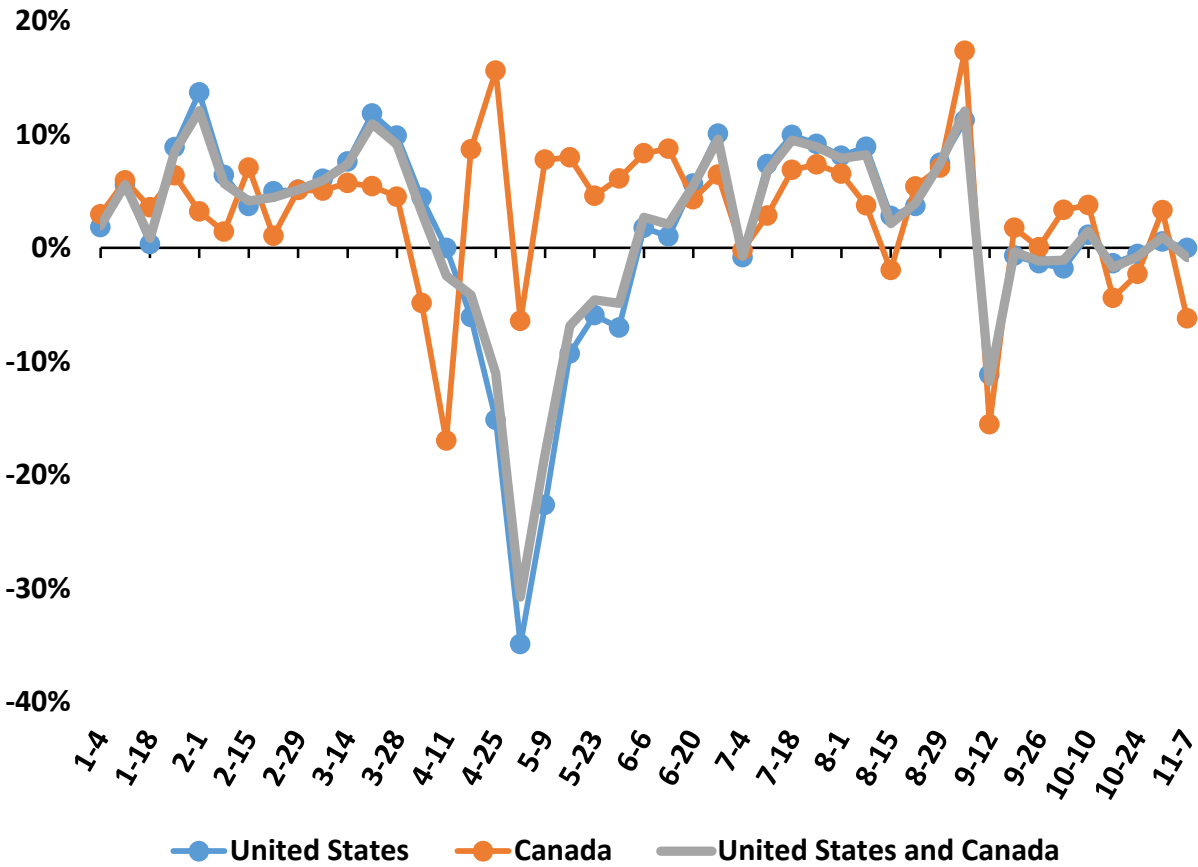


Figure 5. 2020 Percentage Change in Weekly U.S. and Canadian Market Hog Prices, Baseline 2019

Data Source: United States—USDA National Daily Direct Hog Prior Day Report – Slaughtered Swine report (LM_HG201), compiled by the Livestock Marketing Information Center. We show the weighted average net purchase price across all producer-sold hogs. Canada—Agriculture and Agri-Food Canada W042C Red Meat Price Report – Hogs, compiled by the Livestock Marketing Information Center. Futures—Chicago Mercantile Exchange (CME) Group, compiled by the Livestock Marketing Information Center. All relevant price series were adjusted for exchange rate before year over year calculations were made.



Data Source: United States—USDA Actual Slaughter Under Federal Inspection report (SJ_LS711), compiled by the Livestock Marketing Information Center. Canada—Agriculture and Agri-Food Canada Hog Statistics at a Glance, compiled by the Livestock Marketing Information Center.

Figure 6. 2020 Percentage Change in Weekly U.S. and Canadian Federally-Inspected Hog Slaughter, Baseline 2019

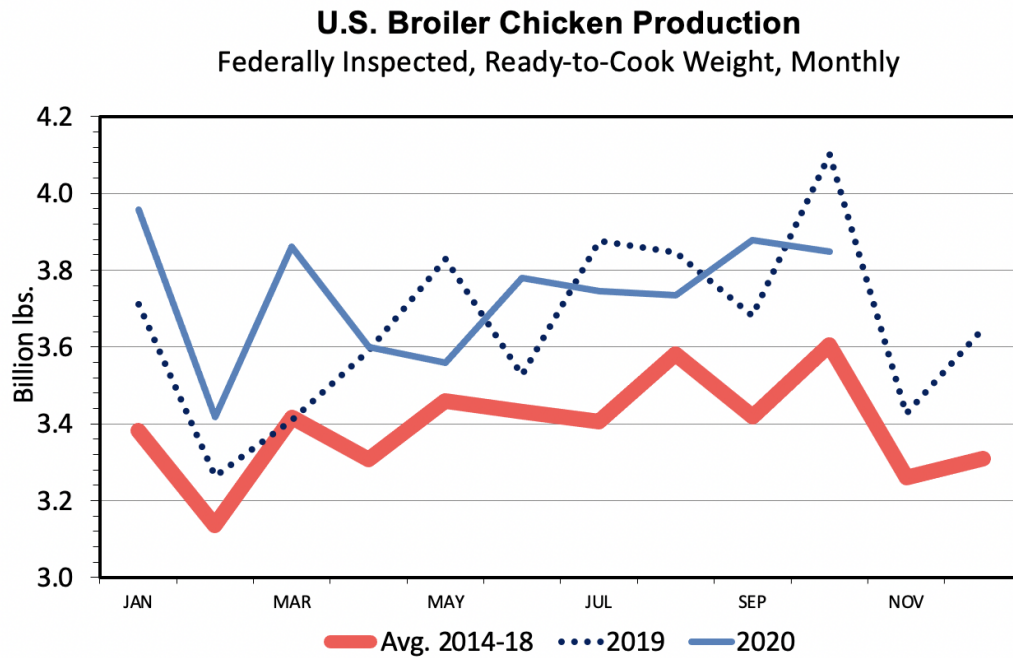


Figure 7. U.S. Broiler chicken production, monthly federally inspected, ready-to-cook weight
 Source: USDA-NASS, 2020c.

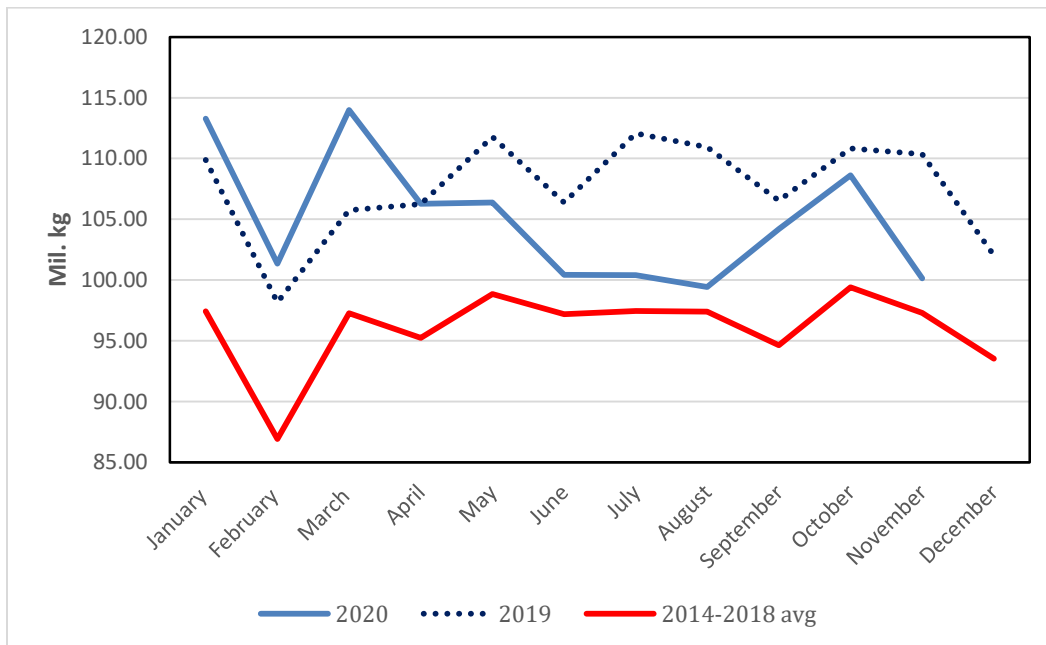


Figure 8. Canadian Chicken Production, monthly federally inspected, eviscerated weight
 Source: (AAFC) <https://aimis-simia.agr.gc.ca/rp/index-eng.cfm?action=pR&pdctc=&r=6>

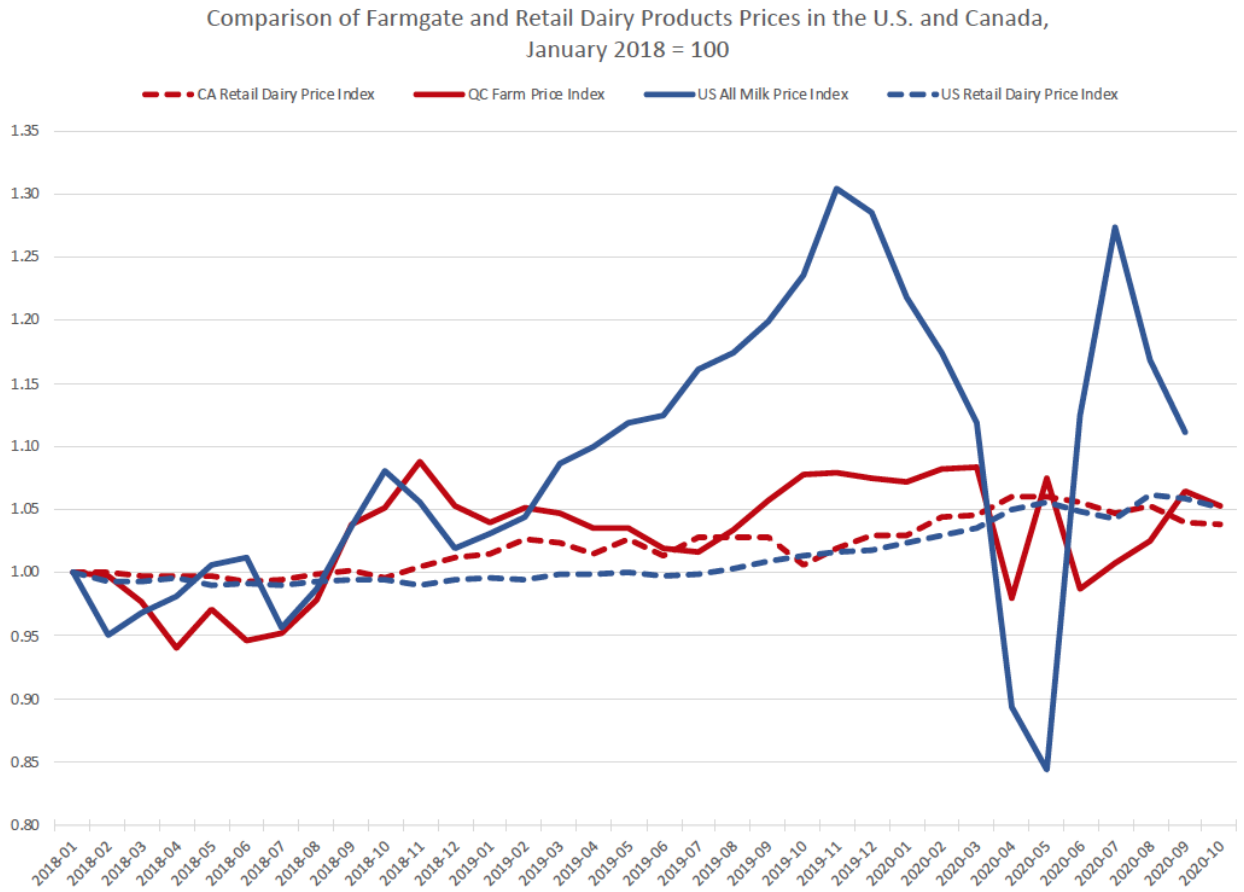


Figure 9: Monthly farm milk and retail dairy product prices in the U.S. and Canada, January 2018 to October 2020 (January 2018 =100)

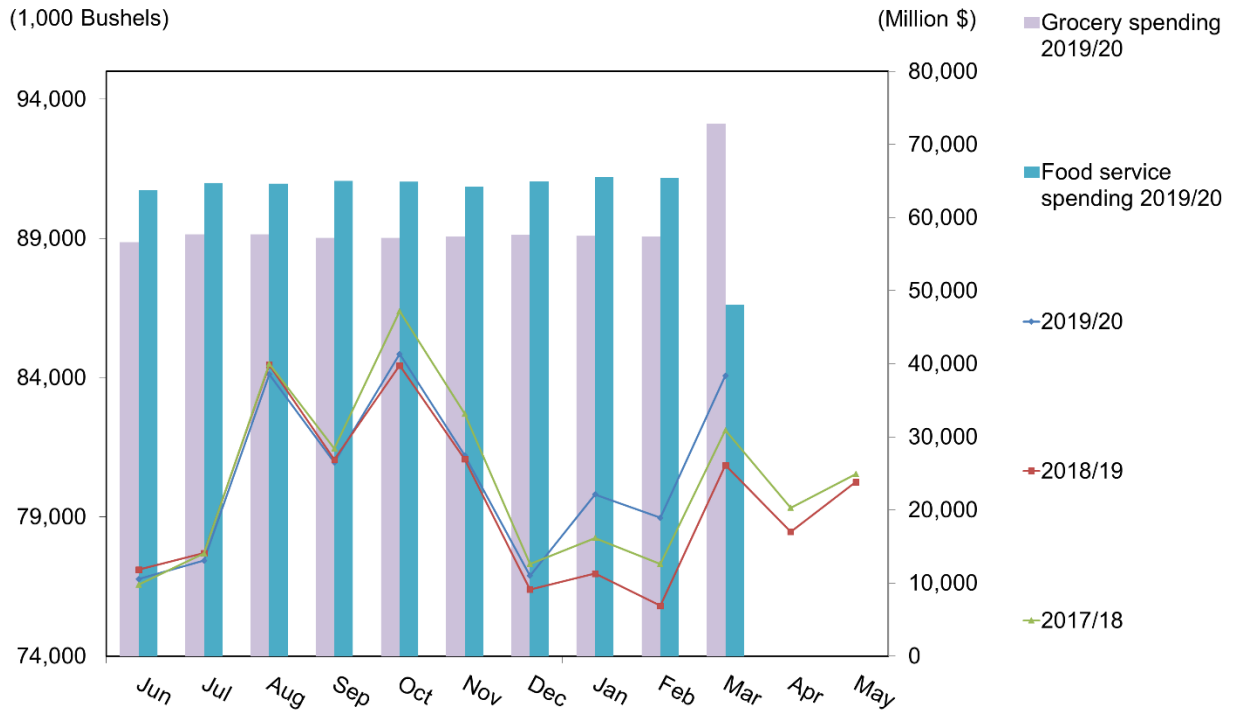


Figure 10. Shifts in U.S. wheat flour production in response to early COVID-19 shifts in consumer spending (USDA NASS, 2020).

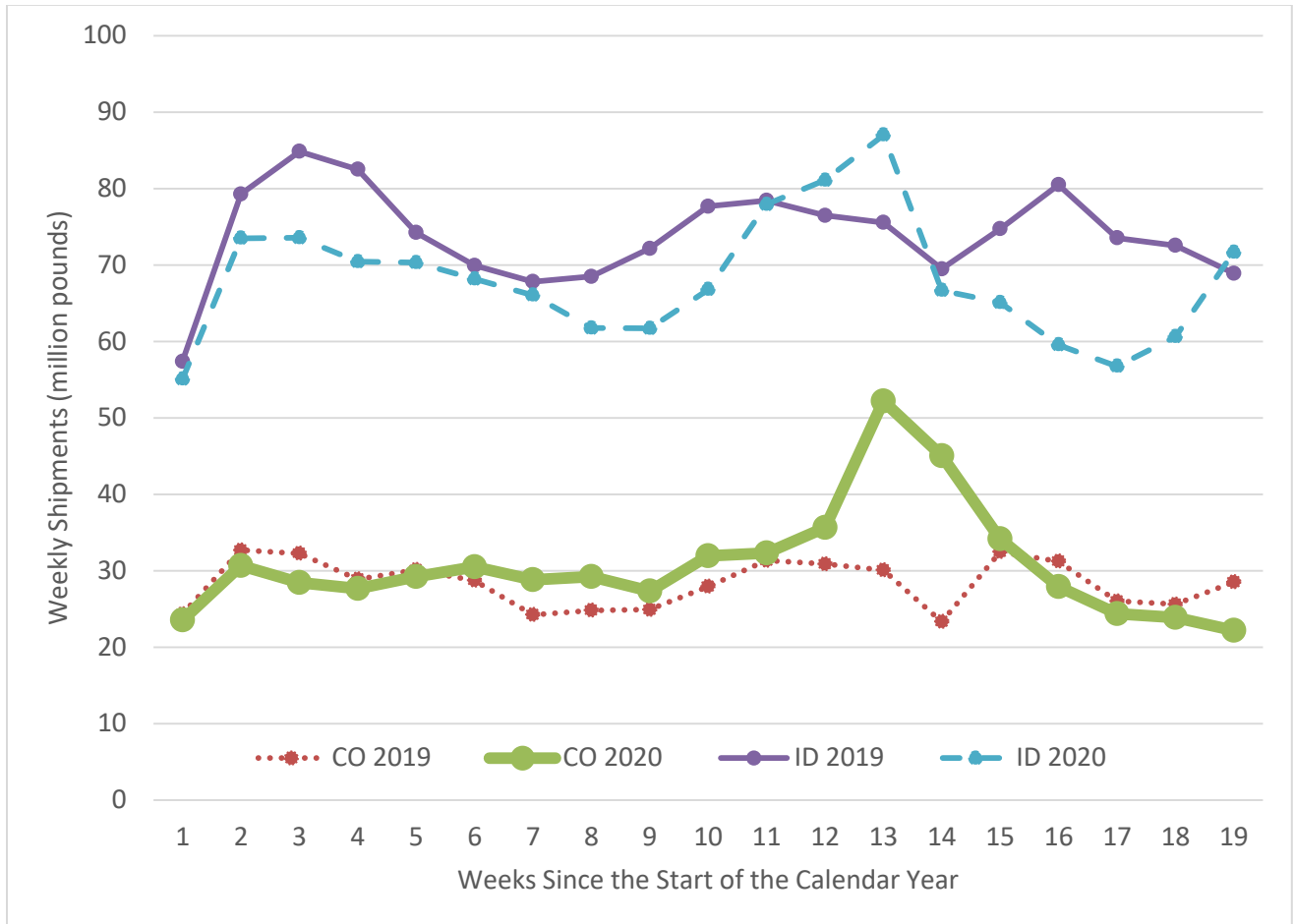


Figure 11. Weekly Potato Shipments, First 19 Weeks in 2019 and 2020 Retail Shipments in Colorado (CO) and Foodservice Shipments in Idaho (ID)

Source: USDA-AMS, 2020c

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Highlights

- Initial stages of the COVID-19 pandemic exposed a vulnerability in agri-food sector supply chains.
- Most sectors have since moved back to near normal conditions.
- Importance of understanding the whole supply chain is growing.
- The trend toward greater automation will continue to accelerate.

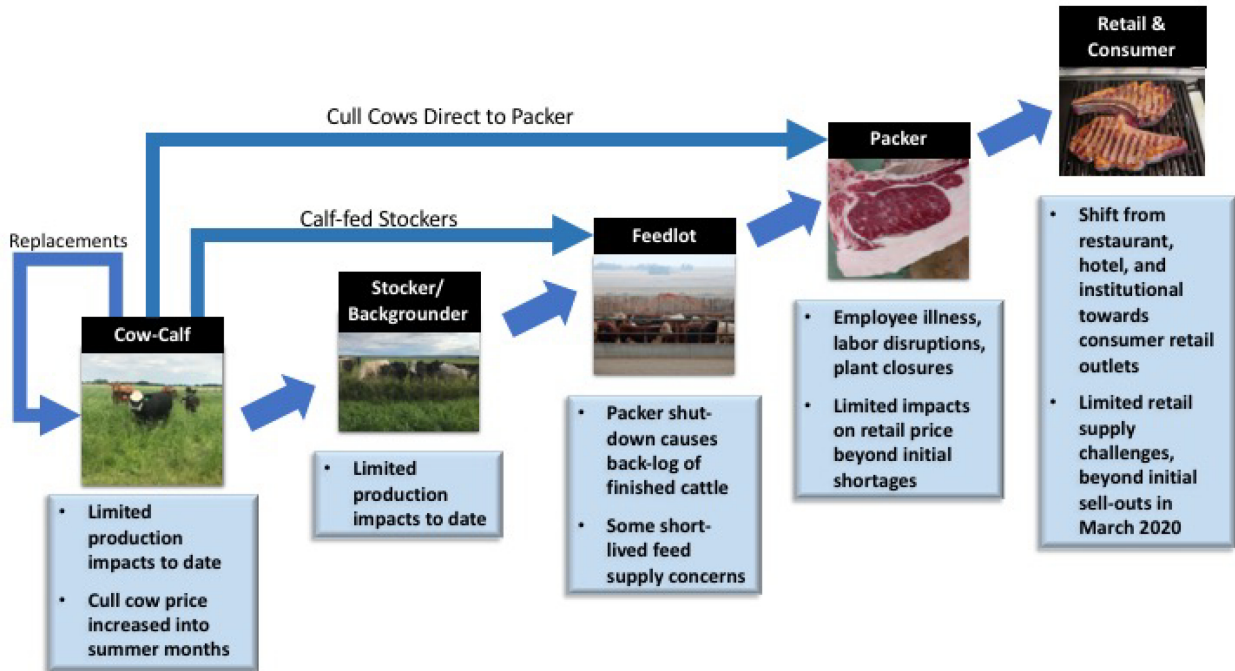
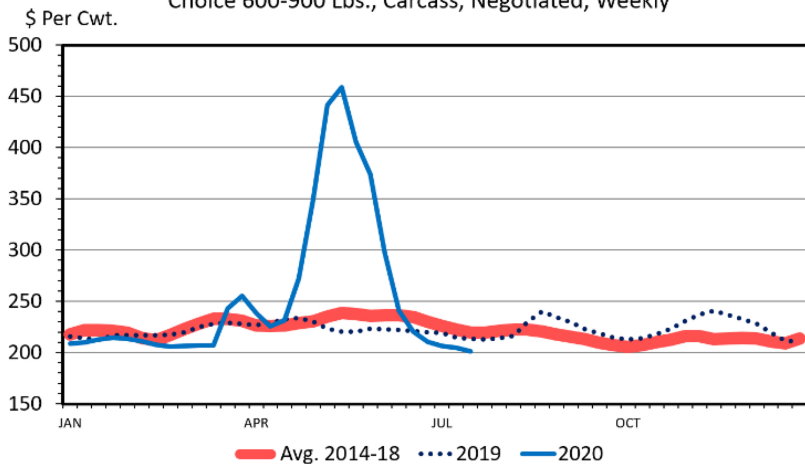


Figure 1

BOXED BEEF CUTOUT VALUE

Choice 600-900 Lbs., Carcass, Negotiated, Weekly



Canadian Weekly AAA Cutout Values

— 2020 — 2019 - - - 5 yr avg

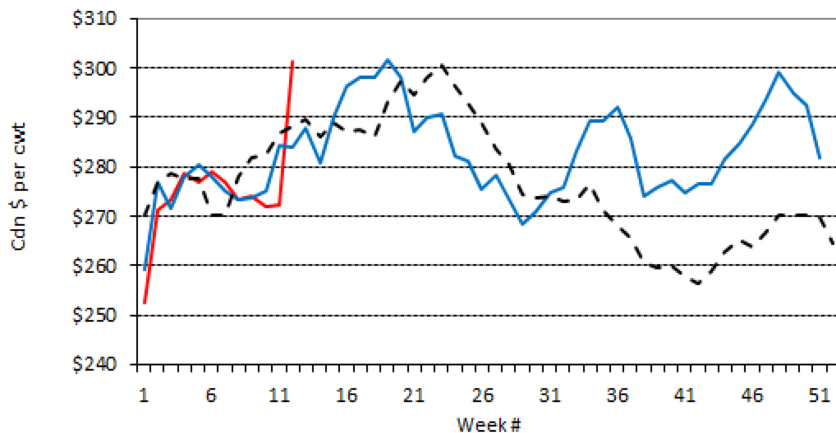


Figure 2

STEER SLAUGHTER

Federally Inspected, Weekly

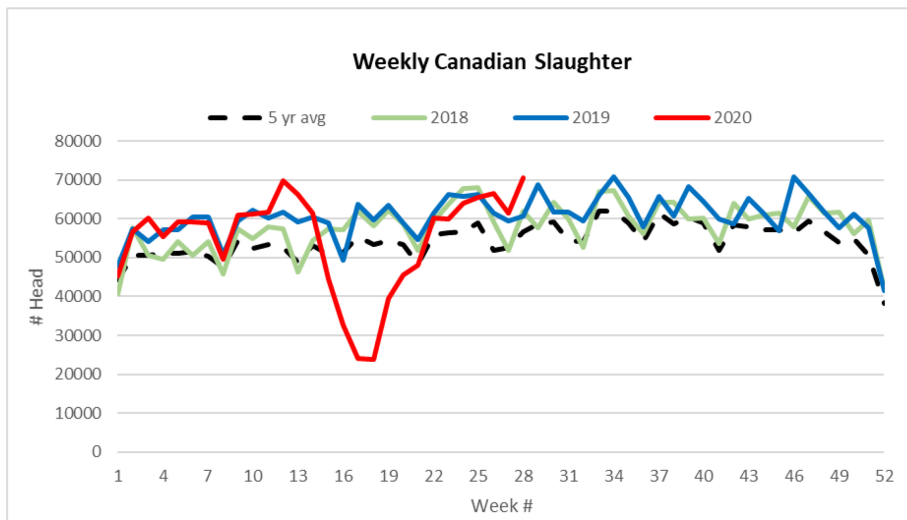
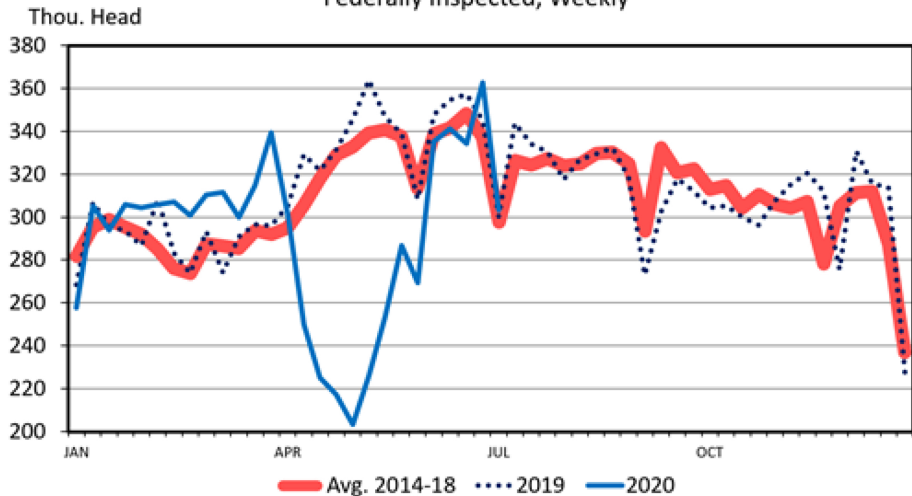
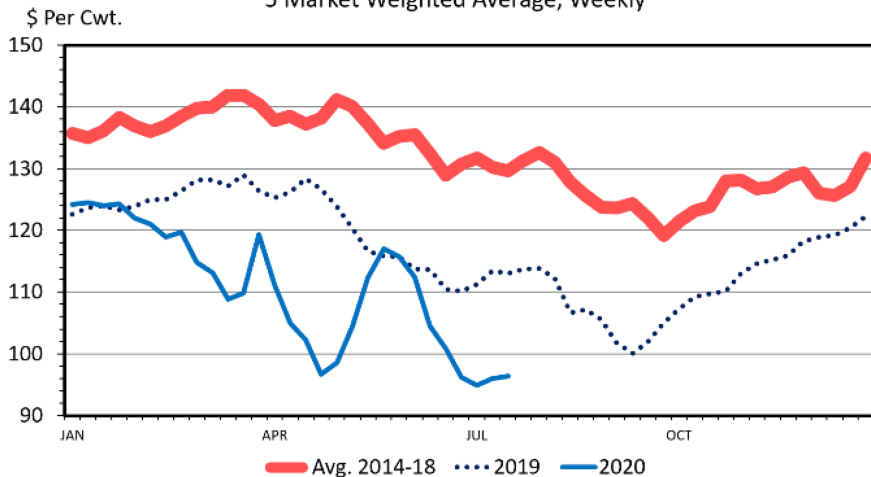


Figure 3

SLAUGHTER STEER PRICES

5 Market Weighted Average, Weekly



Alberta Weekly Fed Steer Price

— 2020
 — 2019
 - - - 5 yr avg

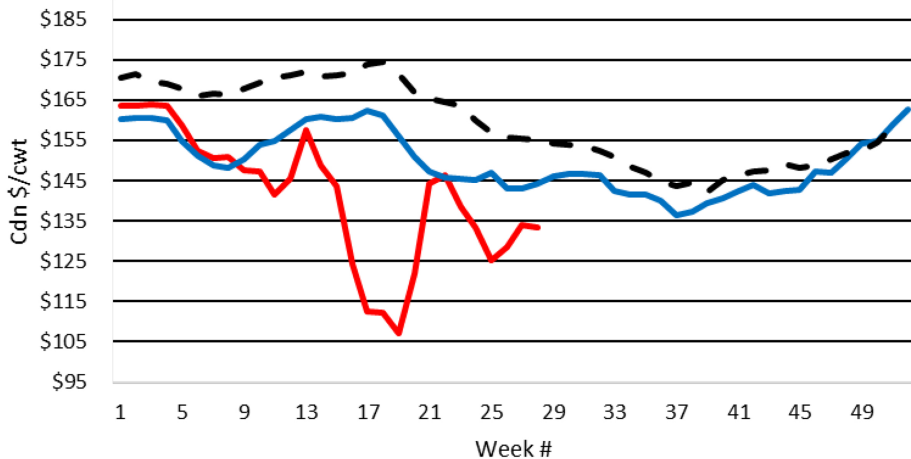


Figure 4

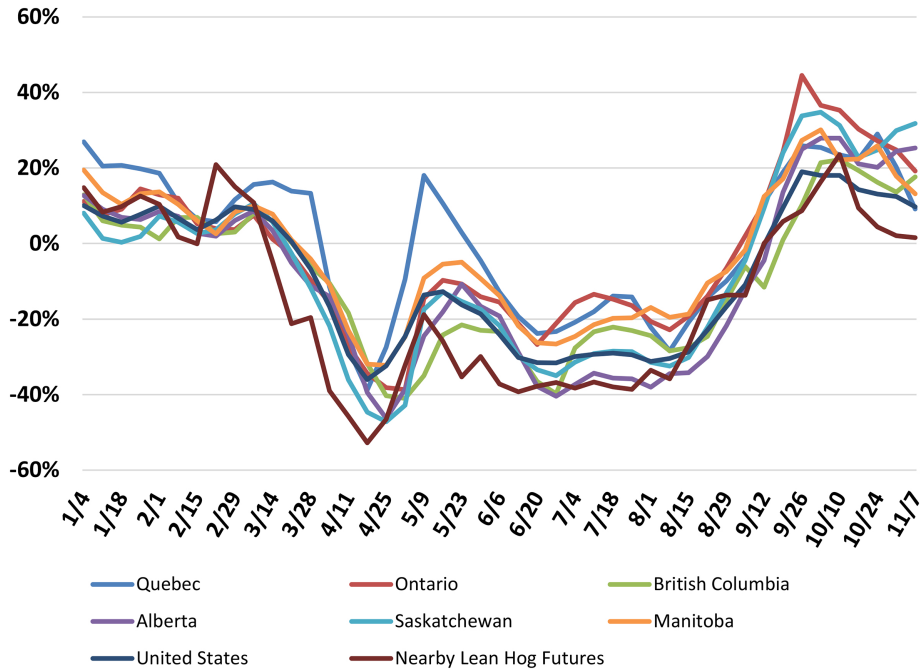


Figure 5

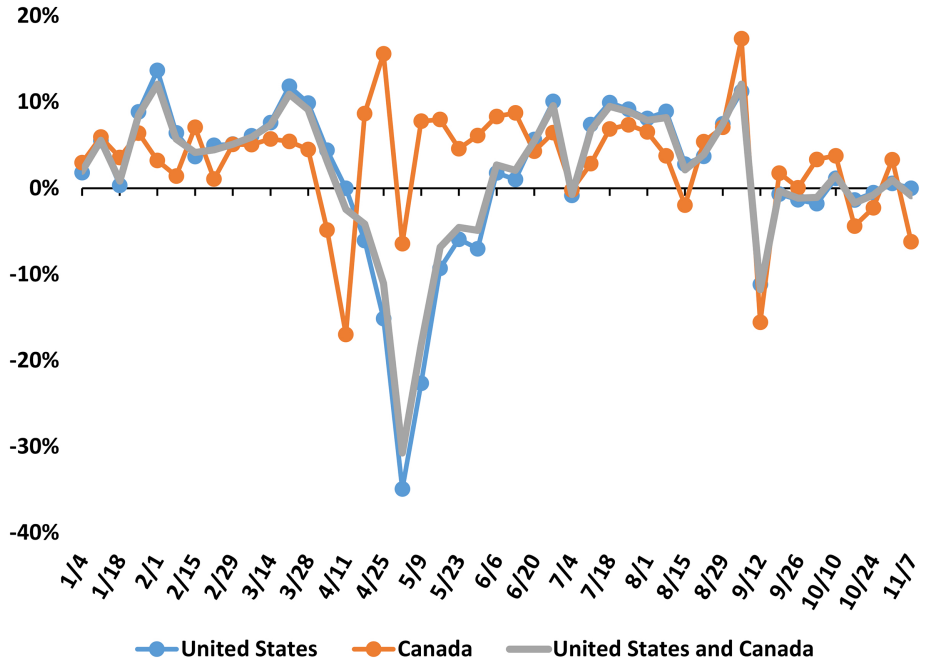


Figure 6

U.S. Broiler Chicken Production

Federally Inspected, Ready-to-Cook Weight, Monthly

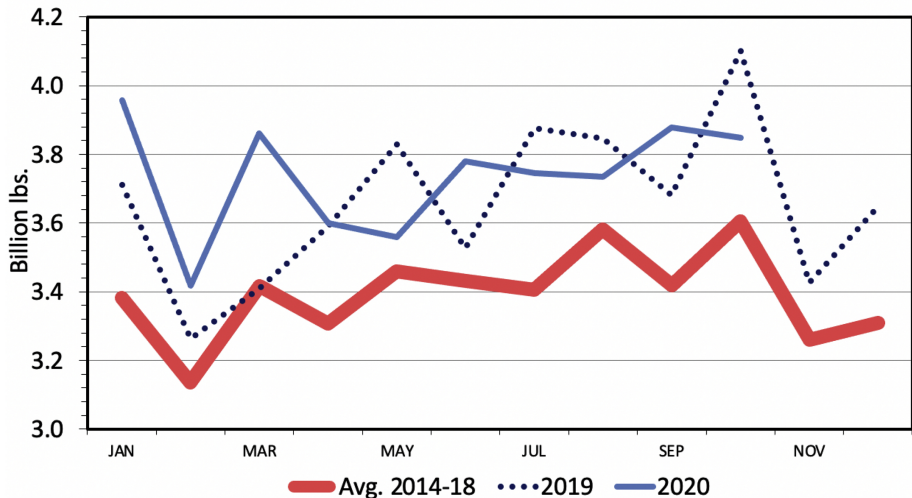


Figure 7

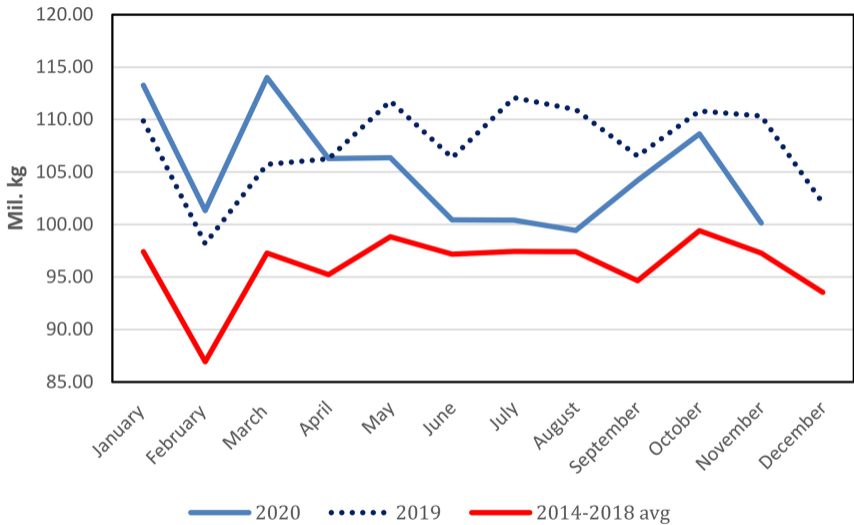


Figure 8

Comparison of Farmgate and Retail Dairy Products Prices in the U.S. and Canada, January 2018 = 100

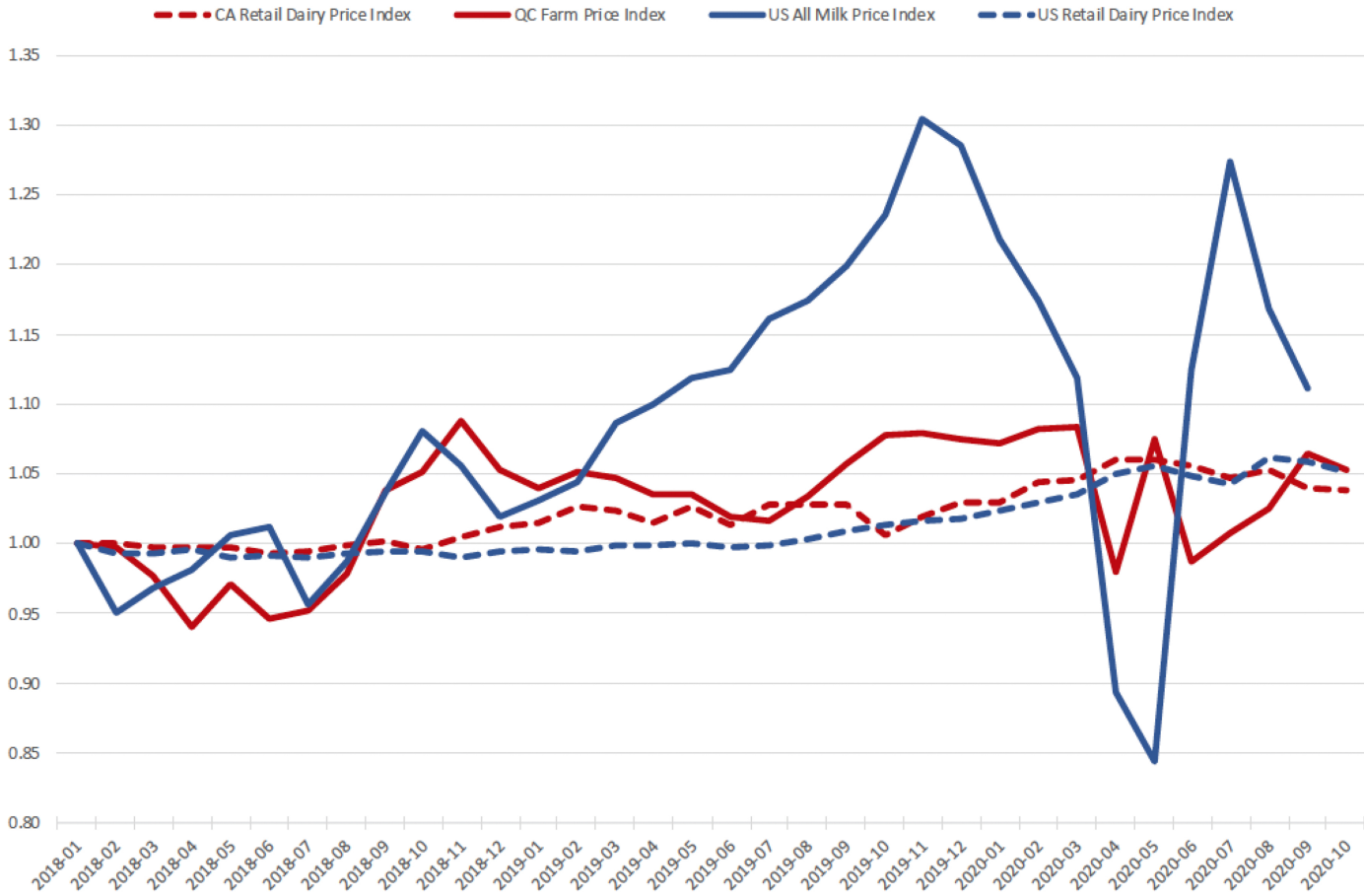


Figure 9

(1,000 Bushels)

(Million \$)

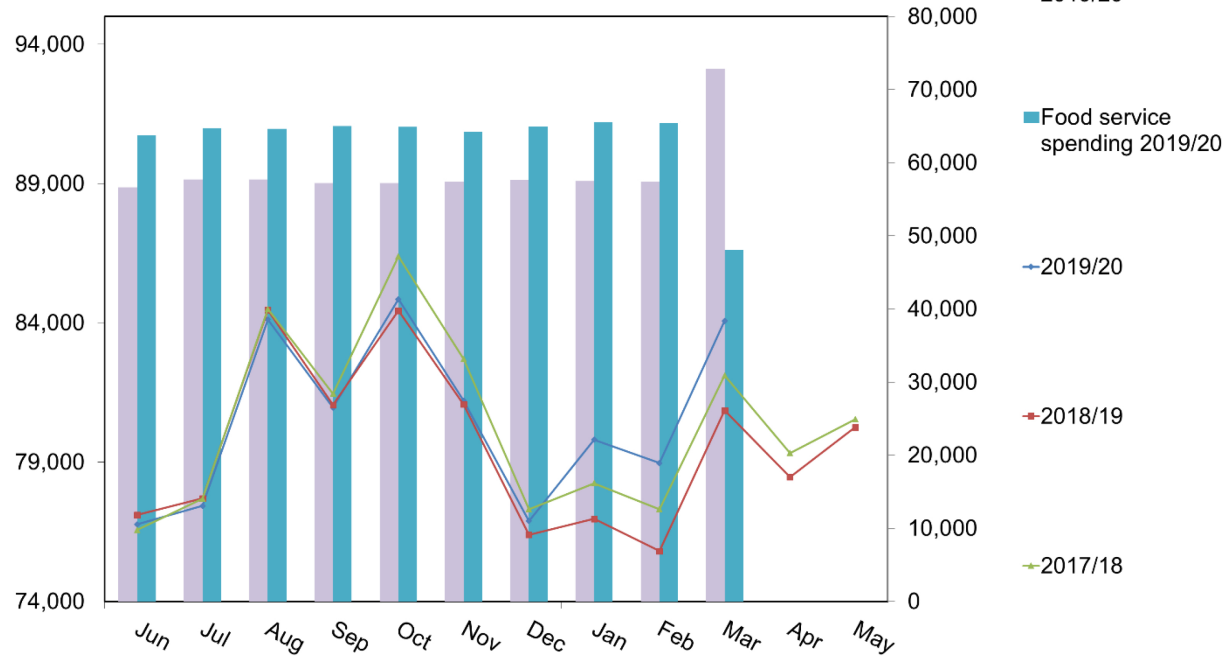


Figure 10

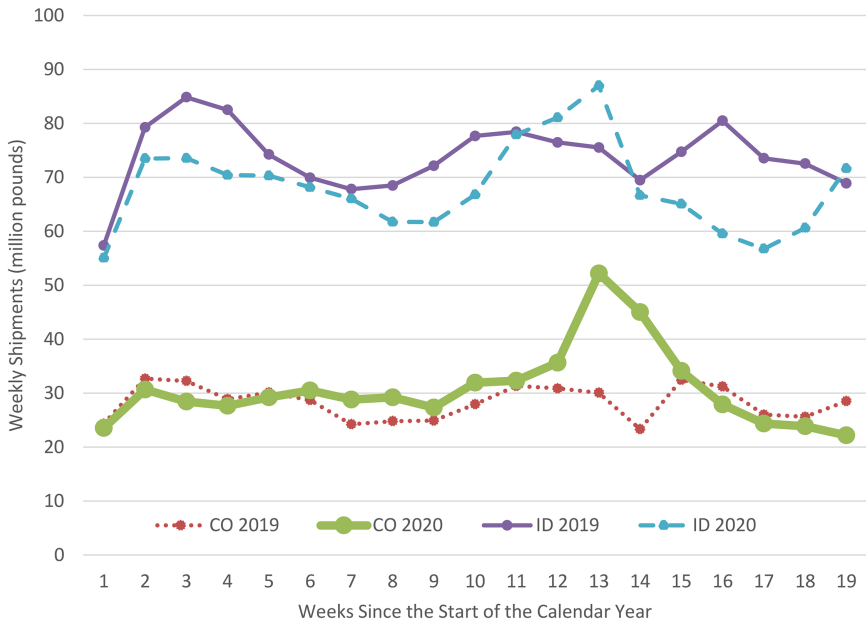


Figure 11