Food supply chain resilience and the COVID-19 pandemic: What have we learned?

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Abstract
A year into the COVID-19 pandemic, this paper reflects on the changes that occurred in agrifood supply chains in Canada and the United States. The sudden shift in food consumption patterns from food service to food retail required realignment of food supply chains. For the most part, food supply chains have performed remarkably well during the pandemic. Cross-border food supply chains have continued to function effectively. The most significant disruptions emerged from workforce outbreaks of COVID-19 in the meat processing sector and in fruit and vegetable production. The paper discusses supply chain resilience and argues that agrifood supply chains are characterized by several important differences that need to be taken into consideration when evaluating resilience. Economies of scale and scope offer economic efficiency advantages in normal times, while investments in adaptability and flexibility can enhance resilience for abnormal times. Potential long-run changes within supply chains include increased automation and digitalization in food supply chains, while investments in infrastructure for online delivery services have permanently altered the food retailing landscape.

KEYWORDS
automation, flexibility, health, labor, meat processing, online delivery, supply chain resilience

Résumé
Un an après le début de la pandémie du COVID-19, ce document se penche sur les changements survenus dans les chaînes d’approvisionnement agroalimentaire au Canada et aux États-Unis. Le changement soudain des modes de consommation alimentaire de la restauration à la vente au détail a nécessité un réalignement des chaînes d’approvisionnement alimentaire. Pour la plupart, les chaînes d’approvisionnement alimentaire se sont remarquablement bien comportées pendant la pandémie. Les chaînes d’approvisionnement alimentaire transfrontalières ont continué de fonctionner efficacement. Les perturbations les plus importantes sont apparues à la suite d’épidémies de COVID-19 sur le marché du travail dans le secteur de la transformation de la viande et dans la
production de fruits et légumes. Le document discute de la résilience de la chaîne d’approvisionnement et soutient que les chaînes d’approvisionnement agroalimentaire sont caractérisées par plusieurs différences importantes qui doivent être prises en considération lors de l’évaluation de la résilience. Les économies d’échelle et de gamme offrent des avantages en termes d’efficacité économique en temps normal, tandis que les investissements dans l’adaptabilité et la flexibilité peuvent améliorer la résilience en période anormale. Les changements potentiels à long terme au sein des chaînes d’approvisionnement comprennent une automatisation et une numérisation accrues des chaînes d’approvisionnement alimentaire, tandis que les investissements dans l’infrastructure des services de livraison en ligne ont modifié de manière permanente le paysage de la vente au détail de produits alimentaires.

1 | INTRODUCTION

In the 2020 special issue of the Canadian Journal of Agricultural Economics, “COVID-19 and the Canadian Agriculture and Food Sector: Thoughts from the Pandemic Onset” (Ker & Cardwell, 2020), I contributed a paper “Food supply chains during the COVID-19 pandemic” (Hobbs, 2020), which was written in early April 2020 during the first few weeks of the pandemic. A year into the global pandemic, this paper provides an opportunity to reflect on what we have learned about food supply chains and supply chain resiliency since that time. To what extent did food supply chains rebound from the initial demand and supply shocks discussed in the first paper, and to what extent are long-run changes evident or still taking shape? How vulnerable were food supply chains to disruptions in logistics, particularly cross-border supply chains, and disruptions in labor supply? What permanent changes have emerged and how might supply chains continue to adapt and adjust in the future? I focus on food supply chains in a Canadian/North American context. For perspectives on the implications of the COVID-19 pandemic for food supply chains and food security in developing countries, see Cardwell and Ghazalian (2020) and Reardon and Swinnen (2020).

1.1 | Initial adjustments

During the first few weeks and months of the pandemic, food supply chains in Canada and elsewhere were subject to several sharp demand and supply shocks that upended normal supply chain operations. The most significant of these was the sudden shift from food service to food retail as people avoided restaurants and public venues over fears of infection, and governments imposed lockdowns in a bid to curb the spread of the virus. Food supply chains geared up to supply the food service sector needed to adapt to the different product offerings, packaging sizes, and distribution channels required for supplying the food retail sector. In the poultry sector, for example, demand for chicken wings and other poultry products popular in food service outlets plummeted and demand for breaker eggs (used in processing) dropped significantly (Malone et al., 2020). In the dairy sector, consumers remaining at home and the temporary closure of cafés saw large declines in the demand for cream and cheese, which were only partly offset by increases in demand for household dairy products such as yogurt, butter, and fluid milk (Weersink et al., 2021). Similar patterns were evident in other agrifood sectors from early March through May 2020. Panic-buying behaviors by consumers, while a highly visible initial outcome of the pandemic (empty store shelves for some products), proved to be a short-run phenomenon.

As predicted in the 2020 paper, the supply chain disruptions caused by the shift from food service to food retail were largely short-run effects, as supply chains adapted and panic buying behaviors subsided. By mid to late summer 2020, most of these markets had stabilized, with retail prices returning to near normal levels. Given the biological nature of agricultural production systems, there are inevitable lags in the ability of these systems to respond to sudden changes in market conditions. Differences in the lengths of breeding cycles (short for broilers, long for cattle), and in seasonal cropping patterns, result in different speeds of adjustment across commodities. The perishable nature of agricultural commodities is a further constraint: dairy farmers deliver milk daily, fruits and vegetables must be harvested when ripe, poultry and
livestock need to be processed at optimal weights. The short-run disruptions to food supply chains resulted in several isolated but highly publicized cases of food waste: milk thrown away, fresh fruits and vegetables rotting, animals euthanized, with efforts made to redirect some of these foods to alternative outlets where feasible (food banks, for example).

One of the persistent refrains in popular discourse emerging from the pandemic has been that food supply chains were vulnerable, were not resilient, or that they somehow failed, with the publicized cases of food waste often held up as “evidence” to that effect. In fact, if we look at what actually transpired in the months following the onset of the pandemic, food supply chains in Canada and the United States performed remarkably well. Certainly, problems arose, particularly with respect to the health of workers in large food (meat) processing plants, which I discuss below. Given the unprecedented nature of the global pandemic, however, disruptions from supply and demand shocks would have occurred regardless of the nature of the food system.

Initial disruptions to food supply chains were particularly problematic for food banks, some of which closed temporarily or were affected by disruptions to wholesale food supply chains. Furthermore, school closures may have exacerbated food insecurity in some communities given the reliance of vulnerable populations on school lunch programs, particularly in the United States. The heavy reliance of vulnerable portions of society on food banks and subsidized meals highlights troubling gaps in social safety net policies, along with social inequalities, but does not necessarily signal a problem with food supply chains or the food system per se.1

1.2 Where did the potential vulnerabilities lie and what did we learn?

Transportation and distribution represent potential vulnerabilities in food supply chains that span large geographical distances and cross international borders. Agrifood trade across the Canadian–US border is important to both countries. The United States is a net importer of beef and cattle from Canada, the US–Canadian hog market is closely integrated with respect to trade flows, and the North American market for fresh fruits and vegetables is also highly integrated, with seasonal production patterns across Canada, the United States, and Mexico. Any thickening of borders to agrifood trade increases costs and reduces the competitiveness of cross-border supply chains.

While there may be other causes of border thickening (buy-national polices, differences in sanitary and phytosanitary measures, etc.), the COVID-19 pandemic does not appear to have weakened the integrity of cross-border agrifood supply chains. Despite movement restrictions, quarantine requirements, and the US–Canadian border being closed to nonessential travel, governments in both countries moved quickly to exempt individuals engaged in food distribution and transportation from these requirements, thereby allowing food and agricultural products to continue to flow across the border. Similar moves were evident in other countries where cross-border supply chains are integral to the food system, for example, within the European Union (EU), and between the United Kingdom and the EU.

An important lesson from the pandemic is the importance of prioritizing open borders for the flow of essential goods during a crisis, such as food and agricultural commodities. The fact that these supply chains were already well established and functioning effectively likely made it easier to put in place steps to ensure their continued smooth operation. The establishment of new supply chains during a time of crisis appears more problematic and vulnerable to the sudden imposition of export restrictions, examples being vaccines, medical supplies, and personal protective equipment.

A second supply chain vulnerability involves labor, including the risk of labor shortages due to worker illness, self-isolation, or movement restrictions. Initial concerns regarding labor shortages in labor-intensive primary production sectors (such as horticulture), which rely on cross-border labor through temporary foreign worker visa schemes eased, with governments taking steps to ensure minimal disruptions to these labor flows (Weersink et al., 2021). Instead, the substantive labor vulnerability within food supply chains in Canada has been worker health and safety. The situation within meat processing plants proved particularly conducive to the spread of the virus given environmental factors (cold and humidity) and operational design (workers standing side-by-side along crowded noisy processing lines) (Aday & Aday, 2020; Hobbs, 2021), as did crowded living conditions for temporary foreign workers in fruit and vegetable production operations.

In the 2020 paper (Hobbs, 2020), I alluded to the potential for supply chain disruptions due to worker illness, particularly in large concentrated sectors such as meat processing, and the need for proactive measures to address this vulnerability. Nevertheless, it was difficult to imagine the scale of outbreaks that subsequently occurred in meat processing facilities. At the time of writing the 2020 paper (Hobbs, 2020), a few meat packing plants in the United States had begun experiencing problems. The situation changed rapidly through April 2020, and by late April, over 30 US meat processing facilities had

1 See Deaton and Deaton (2021) for a discussion of the implications of the pandemic for food security in Canada.
closed due to workforce outbreaks of COVID-19 (Luckstead et al., 2021), with outbreaks also emerging at major Canadian meat processing facilities. Daily processing volumes of beef and pork in the United States were about 40% below 2019 levels through the last week of April and first week of May 2020, with federally inspected slaughter volumes averaging 22% below 2019 levels over the 2-month period from early April to early June (Lusk et al., 2021). According to the US Centers for Disease Control and Prevention, 9% of US meat plant workers were infected with COVID-19 from late March to May 2020, with outbreaks occurring at 239 meat and poultry processing facilities (Waltenberg et al., 2020; Weersink et al., 2021).

While not as severe as in the United States, workforce outbreaks at meat processing plants were reported across a number of other countries, including Canada, Brazil, and in Europe (Aday & Aday, 2020; Luckstead et al., 2021; Tonsor & Schulz, 2020; Weersink et al., 2021). The beef packing sector in Canada is highly concentrated, with three packing plants accounting for 85% of slaughter capacity. Domestic beef slaughter capacity declined by over 60% in late April/early May due to outbreaks of COVID-19 in some of these facilities (Weersink et al., 2021). Similar disruptions were experienced in the Canadian (and US) hog packing sector during the early stages of the pandemic. The introduction of social distancing and other health and safety protocols (masks, screens, etc.) have significantly reduced (although not eliminated) the occurrence of workplace outbreaks in meat supply chains but have resulted in slower processing line speeds.

Temporary closures of major meat processing facilities highlighted the vulnerability of these supply chains to sudden and unexpected shocks, along with the high level of interdependencies within these supply chain systems (Hobbs, 2021). The temporary closure of packing plants reduced the demand for livestock, pushing down cattle and hog prices, while the fall in the supply of meat and processed meats due to plant closures pushed up wholesale prices. The result was widening price spreads between livestock prices and wholesale/retail prices for beef and pork in the short-run (Lusk et al., 2021). By June 2020, retail beef prices had returned to levels comparable to pre-COVID-19, with price disruptions in the hog sector settling out by late summer/early Fall 2020 (Weersink et al., 2021).

While disruptions undoubtedly occurred, the relevant counterfactual is whether a different supply chain system (e.g., less concentrated, more diffuse, local) would have fared any differently facing the same unprecedented global pandemic. Using a simulation analysis, Ma and Lusk (2021) find that a less concentrated US beef packing sector would not necessarily have produced outcomes that were much different. Their analysis suggests that a more concentrated packing sector is better able to ensure the maintenance of a relatively high level of output, while a more diffuse sector (with small plants) is better at ensuring that output does not fall below a minimum threshold; however, the differences are relatively small in terms of economic magnitude. Furthermore, a more diffuse packing sector lowers total welfare due to the loss of economies of scale (and therefore higher prices) (Ma & Lusk, 2021).

### 1.3 Supply chain resilience and long-run changes

During the first year of the pandemic there has been much discussion of food supply chains and food system resilience. Were food supply chains resilient, and how (or should) they be made more resilient? At the heart of this debate is a tension between two worldviews (Hobbs, 2021): one that the current food system is effective and efficient, benefitting from economies of scale and scope that bolster resilience. The other worldview holds that a more dispersed food system, featuring a larger number of smaller firms and localized supply chains offers more security in the face of exogenous shocks that affect critical points in a concentrated supply chain. In reality, we can learn something about supply chain resilience from both of these perspectives.

A concrete definition of supply chain resilience is elusive, variously referring to robustness, adaptability, transformability, recovery, and reorientation. An ecological (systems) perspective emphasizes the ability of a system to absorb change; a psychological perspective focuses on control, coherence, and connectedness in responding to an exogenous shock; supply chain risk management perspectives deal with uncertainty related to logistics; while an organizational perspective focuses on the internal capabilities of an organization (firm) to adapt (Ponomarov & Holcomb, 2009). Furthermore, it is useful to distinguish between the inherent resilience of firms, markets, and supply chains (resilience during normal times) and adaptive resilience (resilience during abnormal times). Drawing upon multiple disciplinary perspectives, Ponomarov and

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2 For a discussion of meat processing in Canada during the pandemic see Rude (2021).

3 Public health guidance was continually evolving through the early stages of the pandemic, including guidance about mask wearing and ventilation, which was not part of public health guidance in most western countries during the early stages of the pandemic but has since become an important component of workplace risk mitigation.
Holcomb (2009) offer the following definition of supply chain resilience: “the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function” (p. 131).

Much of the general literature on supply chain resilience deals with the manufacturing goods sector. Agrifood supply chains are characterized by several important differences that need to be taken into consideration when evaluating resilience, including biological processes, perishability, structure, necessity, and a systems perspective. The production process is inherently biological, leaving little flexibility to adjust production in response to sudden events once crops have been planted, chicks have been hatched, and calves have been bred. While some agricultural commodities are storable (grains and oilseeds), others are highly perishable further reducing the ability to alter delivery schedules at short notice in response to a disruption. These biological constraints apply regardless of the structure of the supply chain.

Although differences exist across commodity sectors, agricultural supply chains tend to be characterized by large numbers of (relatively) small producers sandwiched between concentrated upstream input supply and downstream output processing sectors. The development of differentiated value chains has altered this dynamic in some instances, and there exist some fairly large production operations in the fruit and vegetable production sector, particularly in the United States. Nevertheless, many agrifood supply chains coordinate production flows from a dispersed base of production, which differs from manufacturing sectors such as automobiles and electronics.

Finally, food (along with energy) is a basic human need. A disruption to food (or energy4) supplies due to unexpected events is far more consequential than a disruption in manufacturing goods supply chains. The inability to secure delivery of a dishwasher, an automobile, or a barbecue due to a supply chain disruption may be inconvenient or mildly irritating to consumers, but any threat to food (or energy) supplies will quickly garner public attention. Thus, the resilience of food supply chains (or the food system generally) is an emotive, politically sensitive topic. Indeed, it is often difficult to disentangle food supply chain resilience from the broader concept of food system resilience. Much of the literature on supply chain resilience focuses on resilience from an individual firm’s perspective, while in an agrifood context it is also important to recognize that we are often dealing with a series of interrelated, interconnected supply chains within the broader food system. Love et al. (2021) discuss food system resilience from the perspective of an “action cycle” framework, where the food system absorbs a disruption, reacts, restores, learns, and builds robustness to future events. Food system resilience is defined as “the capacity over time of a food system and its units at multiple levels, to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances” (Tendall et al., 2015, p. 19).

Large-scale food processing plants have economies of scale and scope advantages, lowering costs within the supply chain and providing food efficiently and effectively during “normal” times. Adding capacity and flexibility to enhance resiliency in preparation for abnormal times may sacrifice some of that efficiency, depending on how it is achieved (Hobbs, 2021; Lusk et al., 2021). The lesson from the COVID-19 pandemic is the need to identify and address particular points of vulnerability within food supply chains. Worker health and safety in meat processing plants, and also in labor-intensive production sectors such as fresh fruits and vegetables, emerged as points of vulnerability. Immediate strategies to reduce risks to worker health and safety involved changes to operational procedures and practices, such as social distancing measures, protective equipment, and improved hygiene protocols. While relatively straightforward to implement, these measures (particularly social distancing) slow production lines, reducing throughput. Smaller processing plants are subject to the same labor vulnerabilities as larger processing plants, and indeed may be more labor-intensive given the fixed costs of capital investments.

Longer-run adaptations include increased automation and digitalization. Automation, including increased use of robotics on production and processing lines, reduces dependency on labor. The relative cost of labor as an input is likely to have risen with the need for social distancing and therefore slower processing lines speeds, as well as other measures to improve worker health and safety. Robotics is commonly used in food processing activities involving uniform tasks, such as packaging and quality control. Applying robotics in meat processing is more complicated due to the wide variation in animal and therefore carcass sizes (Hobbs, 2021; Weersink et al., 2021). Similarly, in fruit and vegetable production, increased labor costs arising from new workforce protocols, and recognition that labor may be a point of supply chain vulnerability, make it likely that the technical and economic feasibility of increased automation and robotics will be a focus of future attention in the sector.

The COVID-19 pandemic has fundamentally shifted the transaction and work environment for millions of Canadians with a shift to working from home, reliance on digital communication, and contactless electronic transactions. While these

4The havoc wreaked by system-wide breakdowns of the electric power grid in Texas due to severe winter weather in February 2021 provides a good illustration.
technologies are not new, the pandemic has rapidly accelerated their adoption into mainstream business and personal activities. Once adopted, it is unlikely that these technologies will be disadopted, with an increased rate of digitalization within food supply chains a permanent outcome of the pandemic. Examples include digitalization for quality control as well as quality verification (including the application of blockchain technology), compliance with export certification and other regulatory requirements, improved logistics, food delivery, and digital marketing.

The pandemic has highlighted the value of adaptability and flexibility as components of supply chain resilience. Adaptability and flexibility can be achieved in different ways. Thilmany et al. (2021) discuss the flexibility of local and regional food system actors during the pandemic. With shorter supply chains and stronger interpersonal relationships and networks, these firms were able to pivot more nimbly to alternative marketing channels and buyers. Nevertheless, smaller more dispersed, localized supply chains lack the economies of scale and therefore cost advantages of mainstream food supply chains, and may be vulnerable to localized production disruptions (e.g., due to severe weather events arising from climate change). Without economies of scale advantages, a food system characterized by more diffuse, local supply chains would start from a position of higher prices, further exacerbated by exogenous supply and demand shocks.

The lesson for mainstream food supply chains is the importance of strong interpersonal relationships and networks in providing adaptability and flexibility and as a proactive strategy to enhance supply chain resilience. As Chenarides et al. (2021) point out, in a real options approach to decision-making, there is value in investing in flexibility with respect to alternative supplier and distribution networks during normal times to enhance resilience against future supply chain disruptions. The food service sector has been particularly hard-hit during the pandemic, with closures of food service outlets during several rounds of local and regional lockdowns. This has created additional uncertainty for supply chains supplying the food service sector. Adaptability and flexibility has meant firms in these supply chains seeking diversified market outlets, including adapting to supplying the retail grocery market as well as the growing home meal kit delivery business.

Rapid uptake of online grocery and food delivery services occurred during the early stages of the pandemic, and sustained use of these services is apparent a year into the pandemic. Statistics Canada (2021) reports a 77% increase in ecommerce sales in the food and beverage sector between February and September 2020. Ecommerce sales in general (not just food and beverage) saw a marked increase, peaking in April through June 2020 when many nonessential businesses (including restaurants) were closed during lockdown, surging again in fall 2020 (Statistics Canada, 2021). During the pandemic, many consumers have adopted online grocery shopping for the first time, and although it is too early to tell whether this represents a permanent shift in behavior postpandemic, it seems likely to be the case. Multiple channel shopping has dramatically expanded during the pandemic, with consumers using a combination of on and offline channels, including click and collect, contactless delivery, and in-store purchases (Nielsen, 2020). For income and time-constrained consumers, online channels lower search costs and facilitate temporal planning of purchases (e.g., to take advantage of time-limited price discounts or reduced delivery fees).

Investments in delivery infrastructure, mobile apps, and software scaled up rapidly during the pandemic. This expansion of online delivery infrastructure is here to stay as a component of food supply chains. Third-party delivery providers such as Instacart, Skip-the-Dishes, DoorDash, and Uber Eats act as supply chain aggregators, connecting multiple sellers to a diverse customer base. Food retail businesses have also invested in their own food delivery services, recognizing the shift in consumer expectations regarding online grocery access. If large-scale food retailers perceive home delivery as a key component of their competitive strategy then it is likely they will seek to manage those services in-house rather than outsource to a third-party aggregator. At this stage, however, it is too early to predict how the competition between third-party supply chain aggregators and vertically integrated retail (and food service) delivery will play out.

2 | CONCLUSIONS

A year into the global pandemic, looking back at what transpired, the series of short-run demand and supply shocks that were beginning to reverberate through food supply chains in Canada and the United States in early April 2020 had largely settled down by mid to late summer 2020. By and large, food supply chains adapted surprisingly well to these short-run disruptions. Grocery store shelves remained well stocked, once initial panic-buying behaviors subsided and retailers had adjusted their supply chains in response to the shift in food purchase behaviors from food service to food retail. The potential vulnerabilities of geographically dispersed distribution systems, in particular cross-border supply chains, were

5 This statistic does not distinguish between food retail (online grocery) and food service (online restaurant) sales.
mitigated through proactive measures to keep agricultural and food products flowing across the Canadian–US border. The lockdowns and wholesale shift to working from home that were necessary to protect public health proved particularly problematic for the food service and hospitality sector, and for food supply chains dependent on those outlets. Adaptability and flexibility have become key components of supply chain resilience for these food businesses.

Labor-related disruptions due to worker illness, or the need for workplace social distancing measures to protect workers emerged as a point of vulnerability in some food supply chains, particularly in meat processing and in fruit and vegetable production. Where technologically and economically feasible, it is likely that these sectors will seek ways to adopt increased use of mechanization and automation to address this vulnerability.

The pandemic has shone a spotlight on food supply chain resilience, both the perception of resilience and the reality. Caution should be exercised in calling for major changes in the food system to encourage more dispersed, localized supply chains. There is little evidence to suggest that a different food system with a more diffuse structure would have fared any better in adapting to the unprecedented, sudden short-run supply and demand shocks in the early stages of the pandemic. Indeed, the current food system has proven to be remarkably adaptable. Adopting a smaller-scale, higher cost, less efficient food system will result in higher prices for consumers while remaining vulnerable to sudden exogenous shocks.

Firms have an incentive to invest in enhancing supply chain resilience if the benefits of doing so (e.g., reduced risk of disruption, enhanced reputation/public image) exceed the costs (capital investments, reduced productivity, etc.). While the costs may be reasonably straightforward to assess, accurately determining the short versus long-run benefits to an individual firm of investing in supply chain resilience is more challenging. If private market incentives to invest in supply chain resilience prove to be insufficient, is there a role for policy intervention? This would require careful consideration of the policy objective (what do we mean by resilience, what outcomes indicate resilience) and an appropriate counterfactual (how much more/less resilient would alternative systems be to the same set of exogenous shocks?). It would also require strong evidence that the benefits of policy interventions outweighed the costs, particularly if those interventions included changes to industry structure or the imposition of trade barriers.

The pandemic is still ongoing at the time of writing, and it is difficult to tell at this point how consumers will view food system and food supply chain resilience in the long run. Has the pandemic shifted the food values that underlie consumers’ food purchase behaviors? Has it altered how they view the food system and specific supply chain actors within that system? A growing literature has emerged on the implications of the COVID-19 pandemic for the food and agriculture system, and it seems likely that agricultural economists will have much more to contribute to this literature in the coming years.

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