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How resilience innovations in food supply chains are revolutionizing logistics, wholesale trade, and farm services in developing countries

REVIEW ARTICLE

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Abstract

Developing country food supply chains have been pummeled by a series (and often a confluence) of shocks over the past several decades, including the Russia-Ukraine war, COVID-19, climate shocks from hurricanes to floods to droughts, animal and plant diseases, an intensification of road banditry and local conflicts, and overlaying all these, deep transformation in markets themselves with new requirements for quality and food safety. Yet supply chains have been largely resilient, adapting and bouncing back in surprising ways. We show that this has often involves deep 'pivoting' by one segment or one value chain, and 'co-pivoting' by another to facilitate the former's pivot. We present a conceptual framework and then illustrate with a variety of examples from Africa and Asia, such as pivoting toward e-commerce by Asian retailers and co-pivoting by delivery intermediaries; pivoting toward quality horticultural production by African and Asian farmers and co-pivoting by mobile outsource services for farming and marketing; and building of redundant ports to protect rice milling operations from climate shocks in Asia by agribusiness and logistic firms. The paper provides implications for policy to facilitate these adaptions and for resilience strategies of agribusiness firms.

Keywords: developing countries, food supply chains, pivoting, resilience
JEL-codes: M31, O13, Q13

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1. Introduction

In the years following the outbreak of the COVID-19 pandemic, food value chains have undergone some remarkable adjustments, evolving to meet rapidly changing conditions. Their capacity to adjust has depended on public investments in the hard infrastructure (such as roads and wholesale markets) that form the 'bones' of food systems, as well as government regulations and policies and public and private soft infrastructure (such as financial services, internet systems, logistics, and road security) that are the 'blood' of food systems. The bones and the blood of food systems facilitate efficient exchange and private sector innovations including in resilience to shocks.

The initial food supply chain disruptions in low- and middle-income countries (LMICs) were primarily caused by three COVID-19 responses:

Lockdowns limited the movement of consumers who use retailer and food service outlets, logistics firms that deliver to wholesalers, wholesalers that supply food retailers and farm input retailers, and workers at firms and farms.

Sudden demand surges occurred as consumers panicked and stocked up on staples, such as runs on maize meal in South Africa (Meyer *et al.,* 2022), emptying stores and straining suppliers. Also, income declines caused by the global recession shifted demand from more expensive fruits, vegetables and animal-source foods towards generally cheaper grains, other staples, and processed foods (Laborde *et al.,* 2020).

Internationally, the 'roller coaster' of cargo demand surges and supply plunges disrupted exports and imports, fouling up container inventories for processed foods and farm inputs. These disruptions were exacerbated by port lockdowns and slowdowns caused by a lack of workers to load and deliver products.

In the second year of the pandemic, these factors evolved. First, disruptions associated with the lockdowns faded or became more scattered. The harbors of major trading countries were open, but mandatory quarantines and testing continued to slow the movement of goods (Fresh Plaza, 2022). Moreover, to some extent, consumers continued new behaviors adopted during the lockdowns – such as relying more on food e-commerce and delivery than in pre-pandemic days, including in LMICs such as China and India (Reardon *et al.,* 2021b). Second, demand surged as consumer incomes recovered from 2020. Third, disruptions of cargo shipping, container inventories, and ports, initially perceived as a short-term problem, continued into the medium term. This continued disruption especially affected international commerce (which constitutes some 10% of LMIC food economies), with a particularly large impact on major exporters of non-staples foods, such as Chile. Trade of staple foods (such as grains) was less affected because these products are shipped in bulk and from ports outside of the main maritime highways.

Also, during 2021 the supply chain changes were reinforced by powerful weather-related shocks such as La Niña, which caused droughts in South America and stronger-than-normal hurricanes in Central America and Southeast Asia. Such shocks in themselves are 'business as usual' for domestic and international food supply chains, but climate change has made them more intense and less predictable.

In 2022, the war in Ukraine caused unexpected supply chain disruptions, especially in key staple food and feed commodities (wheat, barley, oil seeds), energy, and fertilizers of which the battling countries (Ukraine and Russia) are major suppliers. It further drove up global food prices and created shortages in availability of food and fertilizers for a range of net food-importing countries.

In the eyes of food industry operators, these waves of disruptions were sudden in their intensity and confluence – but not unusual in their nature. Shocks that induce substantial adaptations in supply chains are not new. Supply chain actors have faced and adapted to continuous disruptions in recent decades. Before COVID-19,

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supply chains had already weathered SARS in 2003, as well as waves of devastating animal and plant disease epidemics in the 2000s and 2010s. They have also had to cope with many extreme weather events.

LMIC food systems are rapidly transforming, making them both more vulnerable and more innovative in the face of these shocks. Food supply chains have expanded and lengthened immensely in the past four decades to serve rapidly growing cities and to meet demand for purchased food from rural areas. This lengthening makes them more vulnerable to shocks than traditional local food economies. But their transformation has also entailed rapid development in logistics, processing, and wholesale practices, with firms of all sizes innovating in supply chains to address transaction costs and innovating in developing resilience strategies to protect their investments.

The key point is that supply chains were clearly shocked by the COVID-19 pandemic, but already had substantial experience and innovation capacity in dealing with shocks. Moreover, supply chains that faced and overcame a series of shocks over time had built up a resilience capacity (such as experience with changing supply routes and technologies, and communicating needs to governments via collective industry associations, such as did the citrus export sector in South Africa (Meyer *et al.,* 2022). As a consequence, many supply chains in developing countries have shown a remarkable capability to adapt and innovate.

During the main lockdowns of 2020, sales of many LMIC supply chains showed a V shape, first plummeting for three to four months, and then bouncing back to normal or near normal (Belton *et al.,* 2021; Liverpool-Tasie *et al.,* 2022). However, many smaller and asset-poor firms operating in structurally poor business conditions, such as those with inadequate infrastructure, were unable to recover. But a growing body of evidence shows that the great majority were able to survive (Nabwire *et al.,* 2022).

The shocks induced food industry firms to make major changes in their strategies and practices. Adaptations by firms to changing market and other context conditions (such as climate shocks) can be continuous or discrete, marginal, or major. We are interested in major, discrete adaptation that substantially alters supply chains, via changes in market channels, technologies, and commercial organization. Such fundamental shifts by businesses in practices and strategy are called 'pivoting' in the business community and in the business management literature (see e.g. Winston, 2014). Here we examine two forms of pivoting in developing country food supply chains, building on earlier analyses in Reardon and Swinnen (2020), Reardon and Vos (2021), and Reardon *et al.* (2021b).

First, we examine the pivoting of food industry firms primarily in their output marketing channels (shifting from or adding on to in-store or in-restaurant sales to e-commerce) and their technologies (shifting from labor-using to capital-using technologies). This pivoting constituted a substantial acceleration of retail transformation into the incorporation of e-commerce (either in competition with supermarket chains or as an adjunct to those chains) that was already emerging in developing regions in the 2010s before COVID-19 as a follow-on to food e-commerce's emergence in the United States and Western Europe in the 2000s (Lu and Reardon, 2018; Reardon *et al.,* 2021a). As we discuss further below, food e-commerce had emerged earliest and developed fastest in China (Zeng *et al.*, 2017) but had been only nascent in most of the other developing countries.

Second, we examine 'co-pivoting' of firms in the wholesale and logistics midstream segments to facilitate the pivoting by food industry firms and thus take advantage of major new opportunities. This involved major adjustments in business strategies and operations of wholesale and logistics providers co-pivoting with food industry firms in response to lockdown regulations related to COVID-19.

To date there has been a dearth of studies of pivoting by food industry firms, especially regarding organizational shifts to e-commerce (or substantial acceleration in e-commerce where the firms had already embarked on it before COVID-19), as well as in business operations in response to major health shocks affecting both output

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demand and labor supply. Also, there is still scant evidence on and analysis of co-pivoting by intermediation segments, especially by delivery intermediaries to facilitate the shift to e-commerce in developing countries.

To address this knowledge gap, in Section 2 we summarize the simple conceptual framework developed by Reardon *et al.* (2021b), but which builds on the recent literature on value chain design (Lu and Reardon, 2018; Zilberman *et al.*, 2019). The framework identifies conditions under which a shock may lead to Schumpeterian structural change when firms fully or partially pivot from current strategies to alternative ones. Section 3 presents, first, an overall contextualization of e-commerce in developing regions, and its acceleration during COVID-19, followed by a taxonomy of key the business innovations and pivoting that are changing operations in downstream, midstream, and upstream supply chain segments. We conclude with implications for policies to facilitate supply chain adjustments in the face of shocks to maximize resilience and a research agenda.

2. Conceptual framework

To understand the emergence of process innovations in food supply chains, we build on the basic conceptual framework of Reardon *et al.* (2021b). Intuitively, the model identifies, at each stage of the supply chain, how much inputs agents choose to obtain from potential sources and how much output to sell to potential buyers, and under what arrangements. For example, intermediaries such as processors must determine how much agricultural produce they should source from the spot market, contracted farms, or farms under their own management. After processing the product, the processor must determine how much to sell directly to consumers, wholesalers, retailers, and exporters. In the Reardon *et al.* (2021b) model, 'pivoting' in the sense of, for instance, creating a new marketing channel, is identified as a technological change. Examples include retailers that pivot from selling in a store to receiving orders on-line and shipping by a delivery intermediary and processors at first only selling to retailers pivoting to sell directly to consumers using a delivery intermediary. Such pivoting is illustrated in Figure 1.

A firm pivoting to a new marketing channel incurs fixed (sunk) costs (Just and Zilberman, 1983). In our case, these refer to costs of machinery, learning, and marketing. Both revenues and variable costs will be affected by systemic shocks. The shocks to the system that we consider have both a demand and a supply component. Shocks like COVID-19 may have a differential impact. They may adversely affect more traditional supply

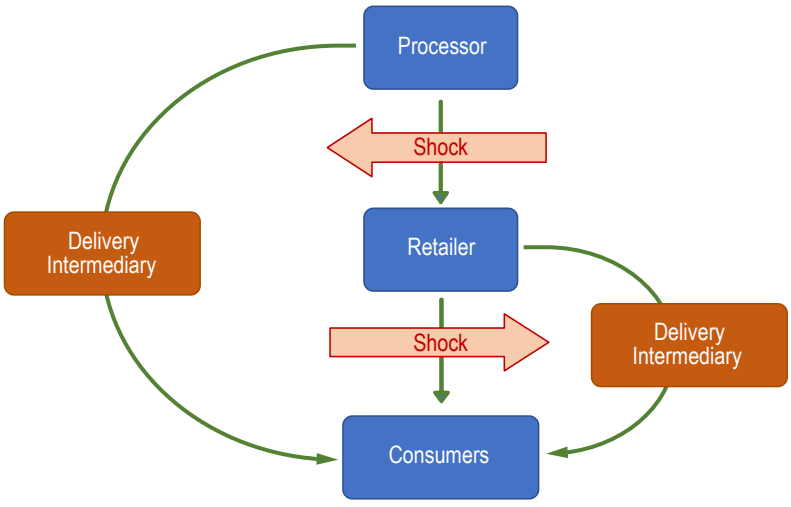

Figure 1. Pivoting by processors and retailers and co-pivoting by delivery intermediaries (Reardon *et al.*, 2021b).

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chains, while more modern supply chains may gain. For instance, the COVID-19 containment measures reduced the demand for restaurant and hotel food services, while increasing demand for food delivery. Policies related to COVID-19 restricted labor mobility and thus may have increased the variable cost of the traditional, labor-intensive marketing channel, as well as production costs.

The fixed costs of the modern marketing channel may represent the costs of establishing the use of a new technology, for example app-based sales systems that allow direct delivery to consumers. The basic model of Reardon *et al.* (2021b) assumes that random shocks will reduce both revenue and marginal revenue in traditional marketing channels, while both increase in modern marketing channels. Furthermore, it is assumed that the shock increases variable costs of the traditional marketing channel, while those are unaffected in the modern marketing channel.

Reardon *et al.* (2021b) show formally that, given those assumption and if marginal costs of purchasing intermediate input are not affected by the shock, a stronger shock will reduce the amount of output sold through the traditional channel under both arrangements and increase sales through the modern channel. Thus, larger shocks are associated with an increase in the relative profitability of the modern marketing channel. If the shock increases the marginal cost of purchasing intermediate input, it may reduce total output of the processor, but the relative profitability of the modern channel will increase. Revenue optimizing firms would thus decide to pivot toward the new marketing channel.

Since firms are heterogeneous, some firms that may have low transaction costs and a relative advantage in terms of adoption of technologies associated with a new marketing channel, may pivot to the new channel even before any shock occurs. Other firms may pivot once the magnitude of the shock exceeds a certain level. Some of the firms with high learning and transaction costs associated with pivoting will go out of business if the shock exceeds a certain threshold.

When there are heterogeneous firms, each will have a threshold at which it will exit the market or adopt the new channel. Thus, this conceptual framework suggests that shocks may change the composition of the processing or retail sector, leading some firms with high variable costs and low demand to exit, and others to pivot to the modern channel and increase market share. We may also expect new entrants to emerge which have a relative advantage in the modern marketing channel.

The framework can be applied to multiple situations. For instance, the 'traditional channel' of supermarkets is retailing to consumers that come to the stores. With digitalization, supermarkets may also retail by e-commerce, perhaps assisted by a delivery intermediary (as in Figure 1). The transaction cost of pivoting to e-commerce is high, but if a shock like COVID-19 reduces consumer demand for buying food at the supermarket and increase the demand for getting food at home, one would observe this pivoting by some retailers, as indeed we illustrate in Section 3. Similarly, some restaurants already established take home service (as an alternative channel), but others may completely pivot to delivery service with the pandemic shock. However, a restaurant with high fixed costs of conversion and insufficient demand may go out of business.

Likewise, we can envision a food processor (as in Figure 1) whose 'traditional' marketing channel is to retail stores, but a disruption like the COVID-19 pandemic may increase the cost of delivery to stores or the processor now expects demand for its product at stores to drop, causing the firm to pivot to e-commerce directly to consumers, taking advantage of new technologies of shipment and packaging and using delivery-intermediaries to facilitate the pivot.

Another example is when labor constraints, such as those caused by worker mobility regulations under COVID-19, put firms with a high labor-capital ratio at a serious disadvantage. If they can, they will pivot technologically by increasing the capital-labor ratio substituting machines for labor, such as in a processing plant. Similar reasoning can explain the co-pivoting by logistics firms to become delivery-intermediaries facilitating e-commerce. For example, a passenger transport firm like Uber may find few clients during

lockdown and switch to or add on a product-delivery service linked to the e-commerce pivoting of retailers and food service.

In the context of acceleration of diffusion of e-commerce with COVID-19, our model predicts several potential patterns of outcomes. In the next section, we provide empirical illustrations for each of the following five cases following from the basic supply chain innovation model:

1. When e-commerce demand increases and the demand for in-store purchases declines, the likelihood increases that retailers either pivot to (or increase prior engagement in) e-commerce.
2. When economies of scale and scope reduce marginal costs of e-commerce, e-commerce supply will increase.
3. When a retail firm considers developing e-commerce capacity and realizes that it has a comparative advantage in building that capacity internally rather than relying on third party partners, it will invest in building this capacity, given credit and other constraints, and rely on third parties (such as delivery-intermediaries) on the margin, for some deliveries or to augment the volume of clientele.
4. When a third party such as a delivery intermediary has a comparative advantage in facilitating the food industry firms' adjustment to e-commerce, either the third-party *co-pivots* to facilitate the food industry firm's *pivot* to e-commerce or a set of third parties *co-pivot*, such as by forming combinations of delivery intermediaries and pure logistics firms.
5. When a processor faces higher costs of accessing labor, if it can, it substitutes machines for labor.

3. Resilience innovations

3.1 Shocks accelerate change building on previous innovations

The disruptions caused by recent shocks like COVID-19 accelerated many ongoing shifts in food supply chain operations. During the past 25 years, the agri-food sector underwent major and rapid changes, especially in developing countries. Financed by large-scale foreign or domestic investors, supply chains modernized, a process that includes restructuring of wholesale and retail distribution, logistics, processing, and input supply to provision rapidly expanding urban food markets (see e.g. Reardon *et al.,* 2019). Upstream innovations included modern farm inputs and new technologies; downstream innovations, our focus here, included expansion of supermarkets, franchised fast-food service, and packaged processed food. In developing countries, the characteristics of traditional markets – including fragmented supply chains, missing service and input markets, inadequate skills, and underfinanced suppliers – have tended to hamper adoption of these innovations.

As a result, two broad modernization modalities have emerged. Some large-scale operators have set up vertically integrated supply chains to control input and output delivery and limit transaction costs. Other large-scale supermarket chains, traders, and food processors employ an array of SMEs to support transportation, logistics, distribution, and delivery. Vertically integrated supply chains have shown greater resilience and capacity to adjust and innovate during the pandemic. Supply chains dominated by SMEs, common in many developing countries, have been more vulnerable. As mentioned, these systems have less capacity to adjust to restrictions on labor movements (when relying on hired labor, rather than family members) and greater susceptibility to disruptions in other input provisioning and transportation (especially where storage and processing capacities are inadequate).

3.2 Supply: resilience and adaptation

In some contexts, these modernization processes have led to strongly dualistic market structures, with modern vertically integrated supply chains serving one market segment and traditional SMEs serving another. Senegal's fresh fruits and vegetables supply chains illustrate the stark contrast in ability to adjust to the COVID-19 shock. The vertically integrated, large-scale modern firms, which exclusively produce fruits and vegetables for export markets, have suffered little impact from the pandemic. These firms were able to

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adapt business operations to circumvent labor restrictions and adjust marketing channels. In contrast, small-scale farms, traders, and handlers operating in Senegal's poorly integrated domestic markets were severely affected by labor restrictions and disruptions in input supply, aggravated by a lack of adequate storage and limited capacity to manage risks (Swinnen and Vos, 2021; Van Hoyweghen *et al.,* 2021).

In Ethiopia, vegetable supply chains were also severely affected by disruptions in transport and in the supply of key farm inputs. In response to the pandemic, the government introduced trade restrictions to protect domestic producers from import competition. The impact on Ethiopian vegetable farmers was mixed: some benefited and some lost. Those farmers who could sell into urban markets benefited from reduced local and international competition and higher prices, but those who could not trade to other areas in the country lost out (Hirvonen *et al.,* 2021). However, Ethiopia's smaller vegetable farms were less affected by COVID-19 disruptions than medium-sized farms, as smaller farms rely less on hired labor (Minten *et al.,* 2020).

This finding is consistent with the more general hypothesis that vulnerability to inadequate labor supply, as resulted from COVID-19 restrictions, shows an inverted U-shaped relationship with farm size (Reardon *et al.,* 2020). That is, small farms that rely on family labor have been largely unaffected by labor restrictions, but vulnerability increases among medium-sized farms with relatively high dependence on hired labor. Resilience has been much greater among agri-businesses large enough to benefit from significant economies of scale and financial capacity; these businesses managed to assure their labor supply by reorganizing labor shifts and/or arranging for safe transportation for workers, as was observed in Senegal's large-scale vegetable export firms.

3.3 Demand: more food purchases from modern retail and through e-commerce

Previous food and health safety crises led to increased supermarket purchases and declines in shopping at traditional wet markets. The SARS epidemic, for example, helped jumpstarted e-commerce in China. The COVID-19 pandemic likewise has increased modern grocery store sales at the expense of traditional stores (Figure 2). Albeit starting from low levels, e-commerce in food retail jumped by over 100% during 2020 in many middle-income countries including Brazil, Indonesia, and South Africa and by almost 50% worldwide. Although Figure 2 refers to consumer e-purchases at the retail stage only, use of e-commerce platforms in other segments of the supply chain such as logistics is growing even faster and fundamentally changing the structure of food business operations, as we detail further below.

3.4 Pivoting and co-pivoting for resilience: e-commerce

- *Sales pivot to e-commerce and delivery*

Adversity sparked innovation in e-commerce and delivery services, as enterprises of all sizes learned to spot opportunities and expand into them. In particular, during the past two years, e-commerce in LMICs has innovated and differentiated to enable participation by retailers of different sizes and different strata of consumers.

'Pivoting' by private food businesses and intermediaries typically leveraged digital platforms and/or new types of logistics business models that were already beginning to emerge before COVID-19. Such innovations in business operations, especially the use of e-commerce, e-logistics, e-payment, and e-procurement platforms to link to suppliers and buyers, proved effective in adjusting to the major supply and demand shocks provoked by the pandemic, and they are likely to endure. While adoption of these innovations may be challenging in some contexts, they provide important new opportunities, particularly for the many small and medium enterprises (SMEs) in developing-country food supply chains. Importantly, these innovations have been wholly market driven and introduced by private operators, though facilitated by existing, primarily publicly

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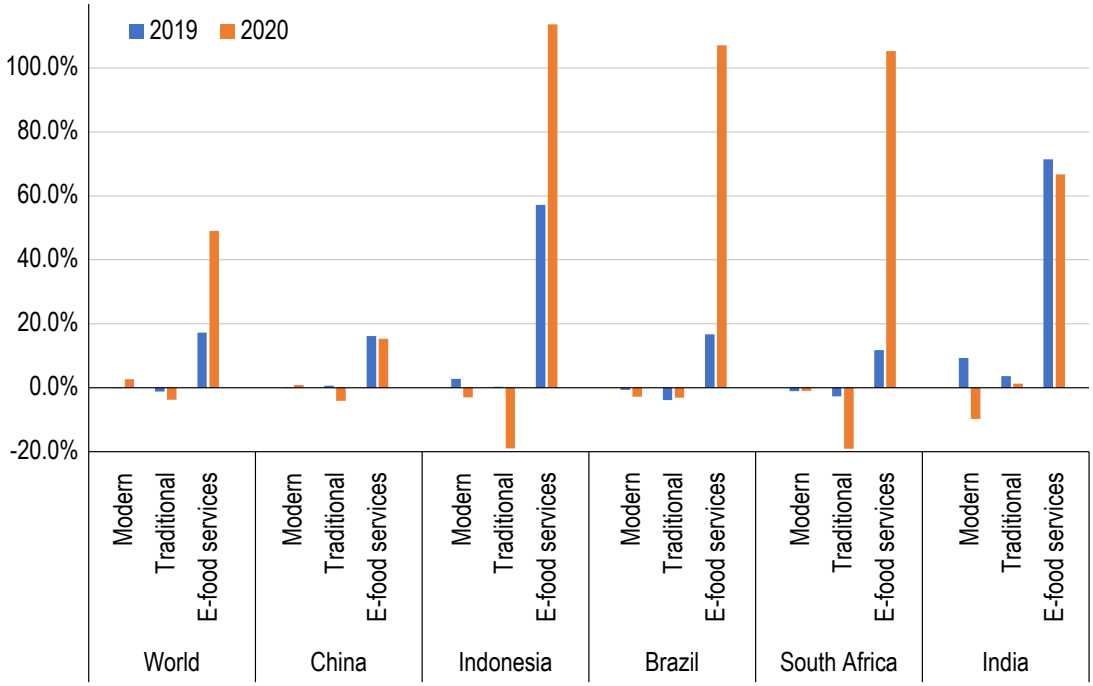

Figure 2. Growth rates of real per capita food purchases at retail level by type of provider in middle-income countries, 2019-2020 (Based on data from www.euromonitor.com, 20 January 2021).[1]

[1] Global coverage for 103 countries. Modern retail stores include convenience stores, supermarkets, hypermarkets, discounters, etc. Traditional grocery retailers are identified by Euromonitor as those that are 'non-chained,' small-scale stores owned by families, and/or run on an individual basis. It does not include informal retailers in open markets or street vendors.

provided infrastructure and regulations for mobile communication technology and other connectivity. Examples of such innovations in LMICs include:

- Expansion of digitally based delivery options into hyper-local and hyper-rapid service. For example, Getir (started in Turkey in 2021) expanded into Western Europe and North Africa.
- Penetration of e-commerce among small and medium enterprises (SMEs), including wet-market stall owners. For example, Getir started Getirçarşı, a division delivering only for SME retailers. In India, Swiggy delivers for food service SMEs and Jiomart (a division of Reliance) provides e-commerce platforms for small retail shops.
- E-commerce 'stretching' into social media. For example, multichannel network companies like TikTok and Kuaishou in China helped e-commerce firms promote their food products, and wholesale markets such as Xinfadi in Beijing provided venues and equipment to support this.

These new ways of doing business also led to new challenges. The shift to digitalization and business in cyberspace has brought vulnerability to cyber-attacks. This became dramatically clear in 2021 when the network of JBS, the world's largest meat firm, was hacked, operations disrupted, and a ransom paid.[7] Such attacks are a major threat to the global food system, including in LMICs, as the digitalization of food markets as well as of internal operations of firms and farms increases exponentially.

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■ *Production pivots toward technologies that save labor and increase flexibility*

Production technology strategies entail choices among factors of production (for example, types of labor and capital). In 2020 and 2021, many LMIC food industry firms faced a shortage of available (healthy) workers. This challenge was exacerbated by the need for many workers to take on new tasks, such as driving delivery vehicles and staffing fast-turnover warehouses that serve e-commerce.

During the lockdowns of 2020, many local workers stayed home, rural migrant workers went back to their villages, and international migrants went back to their home countries while new migrants were denied entry. To attract workers, firms had to invest in reconfigured workspaces for social distancing and in health protection gear. In 2021, food firms still faced severe labor shortages, but with a new twist (especially in developed countries) – despite the lifting of lockdowns, many workers did not return to work. This labor shortage will likely remain a major challenge in 2022.

Firms have been responding in two ways:

- Firms have tried to encourage labor participation with better pay and working conditions and, for migrant workers, governments have loosened visa requirements. For example, citrus packing plants in South Africa have provided incentives and training for local workers to replace migrant workers (Meyer *et al.,* 2022).
- Firms with the financial capacity to invest in new machinery have reduced their need for labor by automating parts of their operations and supply chains. Food firms in developed countries are accelerating such investments, such as in warehousing and logistics in the United States and Western Europe. The same is occurring in LMICs. For example, China opened the world's first fully automated port in Shandong in October 2021. Brazil's pork processor Frimesa invested in automation of its plants in 2020[11] as did Marel with poultry processing in 2021 (Reardon *et al.,* 2022).

This response to the labor supply shock brings societal challenges. As firms (and farms) become more capital-intensive, and need less labor, over time they will likely employ fewer nonskilled workers, despite the pressing need for jobs for the burgeoning 'youth bulge' in the poorer LMICs.

■ *Procurement pivots to increase diversification, flexibility, and redundancy of sourcing, from 'just in time' to 'just in case'*

As food industry firms in LMICs (and developed countries) were slammed by supply chain logjams in both international and domestic markets, first in 2020 and then in 2021–2022, buyers and sellers pivoted to diversify and pursue flexibility.

The procurement of citrus products in South Africa illustrates diversification, flexibility, and the value of years of preparation for crises (Meyer *et al.,* 2022). In 2020, citrus retailers and wholesalers in Asia switched to sourcing more from South Africa when lockdowns caused supply constraints among traditional providers. South Africa's government and its citrus industry were prepared, having already obtained market entry and certifications to sell to Asia in 2018 and 2019. When Europe locked down ports in 2020, South African citrus traders were able to redirect exports to Asia. Moreover, South African citrus supply chains were 'trained' in flexibility, as they had been forced to adapt rapidly to waves of new European phytosanitary regulations over the decade preceding COVID-19. Supply-chain resilience had also been strengthened through investments in improving ports and phytosanitary protocols.

Many food industry firms have found that redundancy of suppliers and assets was crucial for pivoting as well as for absorbing shocks. When one factory or port was locked down or short on labor or materials, others in that firm's supply chain could pick up the work. This strategy is valuable before and after COVID-19. A shift is occurring away from a focus solely on tight supply chains for efficiency, such as maintaining minimal inventories (called 'just-in-time'), toward a 'just-in-case' strategy, which emphasizes

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maintaining a degree of redundancy, flexibility, and diversification rather than strict efficiency (Masters and Edgecliffe-Johnson, 2021).

Examples include:

- The Thai multinational Charoen Pokphand built a series of ports on the river they use for exports, so that if one is washed out by a hurricane another can be activated (Reardon and Zilberman, 2018).
- When consumers in South Africa rushed to stock up on maize meal, they put a sudden, tremendous strain on maize mills. The industry had lamented under-utilization of capacity before 2020 but was able to easily meet the demand surge by moving to full utilization, turning the slack into an asset during the pandemic (Meyer *et al.,* 2022).

These strategies pose a societal challenge as they are likely to accelerate food industry concentration in both LMICs and developed countries. For firms, it is expensive to make the typically substantial threshold investments necessary to maintain options for sourcing and selling, such as Charoen Pokphand's multiple ports. Large enterprises have an advantage, given their greater financial capacity and broader geographic spread of procurement and marketing. SMEs are dependent on smaller supply and marketing geographies and usually cannot afford to make investments in extra facilities or leave capacity unused.

4. Policy lessons: invest in the food system's 'blood and bones' to strengthen firm resilience

The conceptual model and taxonomy and illustrations presented in this paper provide an initial framework for further research including quantification of the behavior and evolution of agri-food supply chains in response to shocks. Quantitative understanding of these dynamic patterns and statistical testing, as well as business management explorations of alternative hypotheses, require quantitative data collection and case studies covering all segments of the food supply chain. These empirical extensions can explore strategic food industry responses, not only to face outbreaks of human-disease pandemics, but also to face shocks related to the spread of livestock disease, food-safety crises, climate change, and conflict. There will be a particular need to study immediate versus longer term responses, hence persistence of pivoting, as well as the impacts of these responses on farmers, SMEs, employment, and consumers. Finally, there will be a need to further explore the pivoting to e-commerce and delivery intermediation in developing countries post-pandemic, and other behavioral changes of firms such as in substitution of labor with capital in the form of an intensification of automation.

As these knowledge gaps need to be addressed, the preliminary assessment in this paper provides some policy lessons. First, governments should embrace actions to enable private sector entrepreneurs, large and small, to pivot as a resilience strategy through innovations in marketing, sourcing, and technology. To facilitate such pivots, governments need to strengthen the support system for food systems – their blood and bones.

Second, investing in roads, wholesale markets, and other infrastructure (the 'bones') is crucial to reducing transaction costs that firms face and thus their flexibility and ability to pivot in sourcing and marketing. Where the bones are strong, such as the South African port system, firms can pivot quickly. Where the bones are inadequate and transaction costs are high, firms are held back as noted in the Africa case of Jumia above.

Third, facilitating logistics, wholesale sectors, and efficient exchange and innovations (the 'blood') is key to the resilience of the whole system. Governments must get the enabling business environment right – facilitating business flexibility by implementing regulations designed to ease doing business, limiting concentration, setting transparent safety standards, reducing cybersecurity risks, and supporting access to finance, especially for SMEs.

These recommendations are critical to ensure resilience, innovation, and flexibility in our food supply chains as new waves of COVID-19 or new shocks arise.

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