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IMPLICATIONS OF SUPPLY CHAIN DISRUPTIONS AND POLICY RESPONSES

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Towards Resilient Food Systems: Implications of Supply Chain Disruptions and Policy Responses

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This paper explores food supply chain resilience and its connection to resilience of food systems more broadly. In terms of availability and affordability, food supply chains have been resilient to a wide range of shocks. Trade plays an important risk pooling role in allowing countries to draw on international markets in the face of domestic shocks. Some domestic policies have helped absorb supply chain shocks, for example support to low-income households or the removal of supply chain bottlenecks. Other measures like export restrictions exacerbate instability. The concept of food systems resilience goes further than availability and affordability of food. It includes broader objectives (like livelihoods and environmental sustainability), and must also anticipate a broader range of shocks, as well as the pressures generated by food systems themselves on the environment. Policy makers should therefore take a more complete systems-wide view of resilience.

Key words: Food supply chains, climate change, trade, food security, blind spots

JEL codes F14, Q17, Q13

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Key messages

- In the wake of COVID-19 and the Russian aggression against Ukraine, concerns about the resilience of food supply chains have risen to the top of the policy agenda. Climate change is also increasingly affecting food supply chains through rising temperatures, changing patterns of precipitation, and more frequent and more severe extreme weather events. This paper explores the resilience of food supply chains, and its connection to the resilience of food systems more broadly.
- In terms of availability and affordability, food supply chains have historically proven to be resilient to a wide range of shocks such as extreme events, pests and animal diseases, food safety shocks, shocks originating in socio-economic systems, and trade restrictions.
- International trade plays an important role in food systems resilience as it allows countries to draw on international markets in the face of domestic shocks. While openness to trade also exposes countries to international price shocks, its "risk pooling" property typically has a net positive effect on resilience.
- Some additional policy measures have helped absorb food supply chain shocks, for instance by supporting low-income households to cope with higher food prices or by helping to remove bottlenecks in markets. Other measures like export restrictions, which have been used frequently, exacerbate instability on global markets.
- The food supply chain lens provides important insights, but is often too narrow to study overall food systems resilience for three main reasons.
    - First, findings regarding the resilience of an individual food supply chain cannot be extrapolated to conclusions about the resilience of the overall food supply; for example, because consumers are often able to switch to other products as substitutes.
    - Second, food insecurity is more commonly caused by problems related to access to food, especially poverty.
    - Third, resilience in food systems must also take into account other food systems objectives, including livelihoods and environmental sustainability, and must consider the pressures generated by food systems on food systems themselves and on other domains.
- If these broader aspects are ignored, policy makers may fail to identify impactful "no regrets" policy instruments (e.g. social safety nets for food security) and they risk strengthening resilience in one area while harming other food systems objectives or even undermining the long-term resilience of the entire system (e.g. by increasing pressures on natural resources).
- Building resilient food systems thus requires a more holistic view, which takes into account the broader set of food systems objectives, anticipates a broader range of shocks (including possible risks that are currently unknown – i.e. "blind spots"), and identifies coherent policy solutions.

Executive Summary

Food supply chains have always been subject to a wide range of shocks, from extreme weather events to trade restrictions. In recent years, however, concerns about their resilience have risen to the top of the policy agenda, as disruptions due to COVID-19 and the Russian war of aggression against Ukraine compound the growing effects of climate change. Some have expressed concerns that globalisation of supply chains, market concentration, and just-in-time supply chain management have created fragilities in food supply chains.

But policy debates around the resilience of food supply chains are not always based on an accurate understanding of how these chains are organised, or how they have historically dealt with shocks. Moreover, these debates, in focusing on whether individual supply chains can continue to deliver, only capture one aspect of food systems resilience (food availability and affordability as a component of food security). A broader perspective on food systems resilience must also take into account other major food systems objectives, including livelihoods and environmental sustainability, and must consider the pressures generated by food systems, and their impacts on food systems themselves and on other domains.

This paper aims to advance the debate on food systems resilience by clarifying these issues. First, the paper reviews trends in the organisation of food supply chains, notably the growing role of international trade and global value chains, changes in market structure and concentration, and the role of just-in-time supply chain management. Second, the paper reviews the historical performance of food supply chains in terms of their capacity to deliver (i.e. in terms of food availability and affordability) in the face of shocks. Third, this paper places the analysis of food supply chain resilience within a broader food systems perspective to assess broader aspects of resilience in terms of other food systems objectives (livelihoods and sustainability) and the impacts of pressures generated by food systems on the resilience of those systems themselves.

The review of historical shocks to food supply chains finds that they have generally proven to be resilient to a wide range of shocks: extreme events, pests and animal diseases, food safety shocks, shocks originating in socio-economic systems, and trade restrictions. Temporary, but sometimes large, price increases appear to be the most common impact. That said, there is currently a lack of conclusive evidence on the impacts of market concentration and just-in-time approaches on food supply chain resilience.

In response to food supply chain shocks, governments often intervene. Some of these policy responses are beneficial, e.g. when they enable low-income households to cope with higher food prices, or when they help remove bottlenecks to the efficient functioning of markets. However, governments also frequently resort to export restrictions, which exacerbate price increases and instability on global markets.

Discussions on resilience often focus on a single food supply chain, which is not a sufficient basis for understanding the resilience of the overall food supply in a country. For instance, consumers are often able to substitute other products, so that even a serious disruption in one food supply chain may have only a limited impact on overall food security. Thus factors which are relevant for the resilience of an individual supply chain are not necessarily relevant for overall food availability. Resilience is also an important basis upon which industries and firms compete as temporary failures or disruptions are often inevitable. Moreover, some disruptions may be a by-product of a process of trial-and-error as firms seek how best to adapt to shocks.

The resilience of food supply chains is merely one aspect of the broader question of the resilience of overall food systems, which requires a more holistic perspective. First, supply chain studies tend to be concerned with food *availability* and affordability, although food insecurity is mostly caused not by temporary shortages in the availability of specific food items, but by households' ongoing lack of *access* to any sources of sufficient food, often due to poverty. Without this broader perspective, such studies tend to overemphasise the importance of strategies to maintain a steady supply of specific foods and fail to identify more efficient policy responses such as a strong social safety net or food assistance programmes.

Beyond food security and nutrition, food systems are also expected to contribute to the livelihoods of millions working along food supply chains, while contributing to environmental sustainability. And while food systems are subject to a wide range of shocks, they are also often a source of pressures themselves,

which can undermine their own resilience as well as the resilience of connected systems. For example, some forms of agricultural production can erode the natural capital on which food systems depend.

If these broader food systems aspects are ignored, policy makers may fail to identify impactful policy instruments (e.g. social safety nets for food security), may end up strengthening resilience in one area while harming other food systems objectives, or may even undermine long-term resilience of the entire system (e.g. by increasing pressures on natural resources).

Enhancing resilience also means investing in identifying all potential exposures and sources of risk. For example, the holistic approach to resilience must focus on the whole range of potential risks for food systems rather than focusing on the most recent type of shock, as the next shock will most likely be different from the previous one. In that sense, enhancing resilience of food systems depends also on addressing resilience blind spots. In addition to "known unknowns", decision makers need to manage "unknown unknowns" –possible risks which are not currently on the radar. Some of these are knowable in principle and could be uncovered through participatory approaches involving a wide range of stakeholders and experts. Other risks may be difficult to imagine, which requires that decision makers maintain adaptability, and build systems that are robust to a diversity of risks.

Building resilient food systems thus requires a more holistic view beyond that used in studies of how single food supply chains respond to a specific shock. This more holistic view of food systems resilience takes into account the broader set of food systems objectives, anticipates a broader range of shocks (including possible risks that are currently unknown – i.e. "blind spots"), and identifies coherent policy solutions. An important open question is which frameworks and governance approaches are best suited to achieve this holistic approach to food systems resilience. Major elements have already been developed by the OECD at the farm level and for supply chains in general. However, further work to identify and extend best practice frameworks and governance approaches for managing food systems resilience is warranted.

1. Introduction

Since 2020, food supply chains across the world have experienced a series of severe shocks. The disruptions caused by the COVID-19 pandemic, the uneven economic recovery from the pandemic, and the unprovoked large-scale Russian aggression in Ukraine have strained supply chains and led to high and volatile food prices. In addition, climate change is increasingly affecting food supply chains through rising temperatures, changing patterns of precipitation, and more frequent and more severe extreme weather events (e.g. droughts, floods, and heatwaves). These affect not only primary production, but also storage, transport, and distribution activities (IPCC, 2022). Understandably, this confluence of disruptions has led to concerns about the resilience of food supply chains. These concerns often focus on the globalised nature of food supply chains; on questions of market structure and concentration; and on the role of "just-in-time" supply chain management approaches, which minimise the amount of goods held in inventory.

However, the public debate suffers from a lack of detailed understanding about the organisation of supply chains, and of the types of shocks which may affect them. Discussions also rarely take into account the broader question of the resilience of food systems as a whole, as opposed to the resilience of a single supply chain.

This paper provides a review of the resilience of food supply chains, and its relation to broader questions of food systems resilience.[1] While various definitions of resilience exist, the term is used here as in other OECD work to denote "the ability to prepare and plan for, absorb, recover from, and more successfully adapt and transform in response to adverse events" (OECD, 2020b).

The next section reviews key trends in how food supply chains are organised and their possible implications for resilience, with a focus on the role of international trade and global value chains, market structure and concentration, and just-in-time supply chain management. This discussion serves as

[1] The terms "supply chain" and "value chain" are often used interchangeably in the literature. Strictly speaking, the term supply chain focuses on the processes involving the physical flow of goods, while the term value chain focuses attention on the monetary flows moving in the opposite direction.

background for the more in-depth analysis in Section 3, which provides a review of historical shocks to food supply chains, and the literature discussing the resilience of food supply chains.

Many studies focus only on the resilience of specific supply chains, without recognising that these chains are nested within more complex food systems. But findings on the resilience of specific supply chains cannot always be extrapolated to the broader resilience of food systems. Studies are often also not clear about what is meant by resilience – of which function of food systems, to which shock, and for which stakeholders.

Section 4 then places the discussion on food supply chain resilience in a broader food systems context. Historically, risks to food security and nutrition have more often been associated with households' lack of access to food (for example, due to poverty or conflict) rather than with physical shortages of food or temporary price spikes caused by supply chain disruptions. Policies to strengthen the resilience of food systems should thus take a broader view rather than focusing on availability and supply chains only. Moreover, food supply chains and food systems do not only provide food security and nutrition, but also contribute to livelihoods, and are expected to contribute to environmental sustainability. And while food systems are subject to a wide range of shocks and pressures, they themselves also cause pressures which can undermine their own resilience in the longer term. Therefore, some degree of transformation of food systems is needed to improve not only their own resilience, but also their environmental and socio-economic performance. These considerations suggest that a more holistic framework is needed to evaluate the resilience of food systems and to design policies which strengthen resilience while maximising synergies and minimising trade-offs across the different objectives of food systems.

Section 4 also discusses the role of blind spots as a risk factor in food systems resilience. Expanding the field of view beyond the risks that are currently measured and beyond the concept of the supply chain would help to overcome some of these blind spots, but an effective approach to building resilience must acknowledge that some uncertainties and surprises are always possible.

An open question is which best practice frameworks and governance approaches are best suited to achieve this holistic approach to food systems resilience. The concluding section offers some suggestions based on previous OECD work, although more work is needed on how these ideas can be translated into practice.

2. Trends in food supply chains and their impact on resilience

2.1. Key concepts

A *risk* for a food supply chain can be defined as a *potential* threat or hazard which may compromise the efficient or effective operation of the supply chain (Ho et al., 2015). Most analyses interpret risks as arising from particular *events* (or *shocks*), and *propagating* through supply chains in ways that depend on the structure of impacted supply chains, on the vulnerability of linkages between supply chain actors, on the regulatory and policy environments, and on potentially complex feedback processes that can magnify or moderate the impacts and persistence of those events.

Risks differ in terms of their *likelihood* and in the magnitude of their *consequences* (or *impacts*). From a societal point of view, these consequences should include not only the financial impacts on supply chain actors but the impact on overall social welfare, including impacts on consumers (e.g. food security, nutrition, prices), workers (e.g. health and safety, job losses), and the environment (e.g. higher total production and environmental impacts associated with food losses along the supply chain due to disruptions).

Some risks are acute (e.g. an earthquake), while others may be more chronic (e.g. depletion of an aquifer due to excessive water use). Within food supply chains, significant disruptions may be caused by acute risks with a low likelihood but with a large potential impact (Zhao et al., 2020). Extreme weather events are one example, and several studies have examined these as a source of risk in food supply chains. Yet other aspects of risk are less well understood. As noted below, complex organisational structures of modern food supply chains, such as the role of global value chains, market structure and concentration, and just-in-time supply chain management might influence the emergence and propagation of shocks.

Supply chain resilience to a particular risk can then be interpreted as the capacity of supply chain actors to prepare and plan for, absorb, recover from, and more successfully adapt and transform in response to adverse events (OECD, 2020b). This can involve reducing the likelihood, or the consequences, of a given risk (Rice and Caniato 2003; Ponomarov and Holcomb, 2009, Heckman et al., 2015).

In reviewing the literature on supply chain resilience, Tukamuhabwa et al. (2015) identify several "resilience factors" that underpin these capacities, including:

1. *Diversity in supply chain nodes*: Supply chains can be considered as networks with nodes and linkages. Diversity here means avoiding potential "chokepoints" or "critical nodes" by ensuring that each supply chain process has multiple pathways.
2. *Connectiveness*: For food supply chains, connectiveness relates to the physical logistics and trade of transporting food products between nodes, and the transactions that determine this trade.
3. *Redundancy*: The ability of a firm or supply chain to call upon reserve resources (e.g. stockpiles of inputs, inventories of final goods, reserve processes, cash reserves, etc).
4. *Visibility*: Maintaining visibility of the structure, functioning, and surrounding environment of all supply chain nodes and links in real time. These may include early warning indicators and information sharing between supply chain actors.
5. *Learning and adaptive planning*: The ability of supply chain actors to plan for risks, reducing the likelihood or negative consequences of events, in the context of a continuously evolving risk landscape.
6. *Governance and supply chain coordination*: Governance and supply chain coordination enables the effective implementation of other resilience factors (e.g. information sharing and adaptive planning).

These factors affect the resilience of *individual food supply chains*. But what is relevant to individual supply chains is not necessarily relevant for the overall food supply, and vice versa. A shock disrupting the supply chain of one individual item may have large effects on companies along the chain, but only limited effects on the overall food supply, as was the case for the shortage of mustard in the European market in 2022 following poor harvests in Canada. Conversely, a shock may have limited effects for global supply chain actors but may be highly disruptive to the food supply in a particular region, as was the case for the disruptions in Lebanese grain imports following the explosion in the Port of Beirut in August 2020.

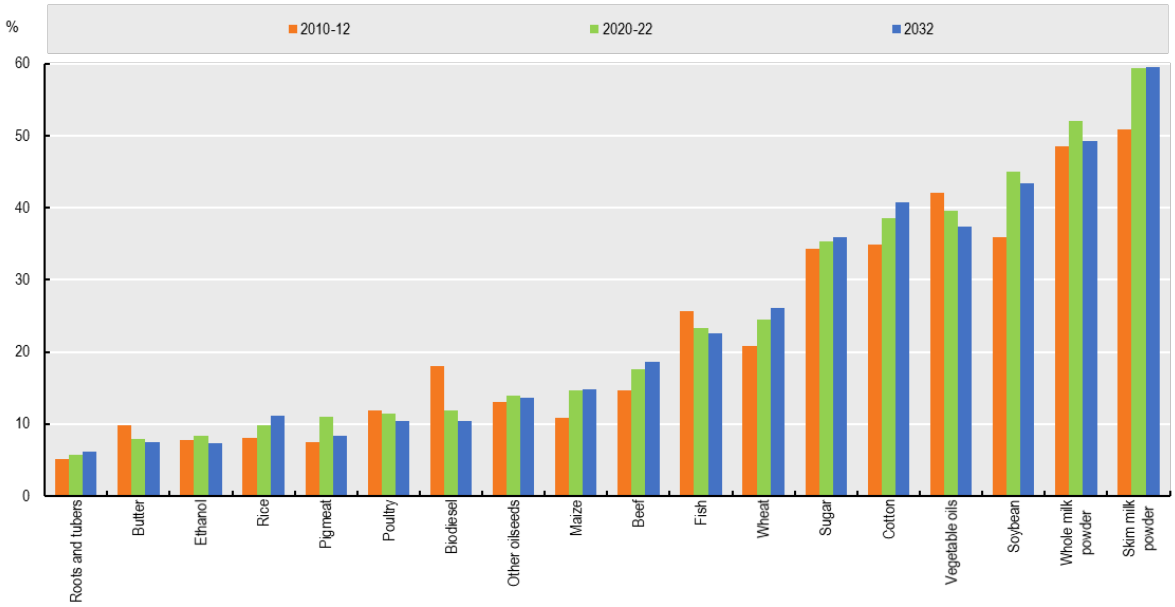
Another important caveat is that some short-run effects of supply chain disruptions, such as price increases, may play an important market function in stimulating firms to overcome these disruptions, for example by diverting supplies from elsewhere or switching to less costly alternatives (in the case of inputs). Price increases may also affect the rate of food loss and waste. For example, high prices may incentivise supply chain actors to take greater care to avoid food losses, while consumers may be willing to accept lower-grade products than they would otherwise. These reductions in food loss and waste would then relieve pressure on the supply chain. Hence, some caution is needed to avoid mistaking important market functions and adjustment processes as indicators of system vulnerability, and in drawing broader lessons about food systems resilience from the literature on the resilience of individual food supply chains.

2.2. The role of international trade and global value chains

Discussions on the resilience of food supply chains are often framed in terms of a perceived dependence on global markets. While international trade plays an important role in food systems, the exact role of trade differs depending on the type of agricultural commodity: trade can play an important role for tropical commodities such as cocoa, coffee or tea (where almost all of production is exported), but may have less impact on the supply chain resilience for agricultural commodities that are less traded.

Data from the OECD-FAO Agricultural Outlook indicates that the share of global production traded internationally is about 10% or less for rice or poultry, and less than 20% for maize and beef (Figure 2.1). Similarly, less than half of the global production of cotton, sugar, or soybeans is traded internationally. Globally, about 22% of all calories produced are traded internationally (OECD/FAO, 2021; 2022).

Figure 2.1. Share of production traded by commodity



Note: Figures are computed as global exports over global production (in volume). Figures for 2032 are projections from the *OECD/FAO Agricultural Outlook*.
Source: OECD/FAO (2022), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

While trade plays an indispensable role in the global food system, for most commodities a majority share of food supply chains therefore operates within a single country. Most agricultural commodities have a low value-to-weight ratio, and perishability creates an additional challenge to long-distance transport; furthermore, global trade in agri-food commodities is encumbered by many restrictive and market distorting trade policies.

However, some of these trade barriers have been reduced somewhat over the past decades, facilitating a strong growth in agro-food trade. Since 1995, international trade in food and agriculture has more than doubled in volume terms, with emerging and developing economies accounting for one-third of total exports (FAO, 2020). Growth has been especially pronounced in global value chains (GVCs), defined as value chains in which products cross international borders at least twice (OECD, 2020d; FAO, 2020; Barrett et al., 2020). About one-third of trade in agricultural and food products occurs in global value chains, as primary products are exported for processing and then re-exported (FAO, 2020). Despite significant growth in global integration in the last two decades participation in GVCs is lower for agro-food sectors than for other sectors (Greenville, Kawasaki and Beaujeu, 2017).

The role of trade and GVCs differs by region. Expressed in calorie equivalents, imports account for some 20% of consumption in most regions (as well as at the global level), except in North America (where the share is less than 10%) and the Near East and North Africa (where the share is above 60%). The share of total production exported (expressed in calorie terms) also varies across regions. In Latin America and the Caribbean, more than 40% of calorie production is exported; in Sub-Saharan Africa and in Developed and East Asia, this share is less than 10% (OECD/FAO, 2021; 2022).

The organisation of food supply chains also differs by country and product, in ways which can shape the resilience of a supply chain to certain types of shocks. For example, supply chains differ in the mode of transport they use. Broadly speaking, cereals and oilseeds are typically transported in bulk (in ships and barges); meat and fresh dairy products are often shipped in refrigerated containers and trucks; while some perishable products with a high value-to-weight ratio may be transported in the bellies of passenger planes. These specifics matter for resilience, as became clear during COVID-19 when air transport was heavily disrupted, while container and truck transport faced some disruptions, and bulk freight was mostly unaffected.

The relatively low *direct* role of international trade for some commodities and regions may obscure larger indirect effects. For example, while the share of livestock products traded is relatively low, livestock production itself often relies on animal feed, for which international trade is more important (as seen from the higher share of soybean production traded globally). Crop production, too, depends on internationally traded inputs such as fertilisers. Moreover, international markets determine or influence prices for agricultural commodities, even those with relatively low trade shares.

International trade is also integral to resilience in food systems. While food production in a single country is vulnerable to many possible shocks, at a global level the supply of food is typically much less volatile. International trade thus acts as a risk pooling mechanism, enabling countries to draw on international markets in the face of domestic shocks (OECD, 2013).

Burgess and Donaldson (2010) provide a striking illustration of this mechanism at the intra-regional level in the context of colonial India. Prior to the spread of railroads in India, local rainfall shortages had large effects on famine intensity. As railroads spread, however, this link between local weather and famine disappeared almost completely. Such improvements in infrastructure (transportation and storage), as well as transparency regarding supply, demand, stocks, and prices, can contribute to the effectiveness of trade.

While the risk pooling aspect of trade leads to lower volatility, at the same time openness to trade also exposes countries to international price shocks. On balance, studies have concluded that although large international price spikes do occur occasionally (as in the wake of the Russian invasion of Ukraine), the positive effects of trade typically dominate (Brooks and Matthews, 2015).[2]

Yet, this risk pooling function of trade can easily be undermined by policy responses that distort international markets. For instance, when global food prices increase, some countries are tempted to impose export restrictions or outright export bans in an attempt to stabilise domestic prices. But this puts further upward pressure on prices in the international market. As is discussed in the review of evidence on shocks and resilience in food supply chains in Section 3.2, such “beggar-thy-neighbour” trade policy responses can at best stabilise domestic prices in some contexts at the expense of other countries; and if many countries seek to transfer price risks to others, they are unlikely to be effective.

Table 2.1 provides an overview of the extent of export restrictions in 2008 at the height of the 2006-8 food price crisis, in 2020 during the COVID-19 crisis, and in 2022 in response to the Russian invasion of Ukraine. During the 2006-8 food price crisis, 33 countries introduced export restrictions covering in total 18.7% of global calories. During the COVID-19 crisis, some countries imposed similar measures but, overall, the impact of export restrictions on global markets was less pronounced than in 2008. However, in the wake of the Russian invasion of Ukraine, export restrictions have again reached proportions seen during the 2008 food price crisis (Laborde Debucquet and Mamun, 2022). In the first three months of the war, many countries introduced export restrictions targeting grains, sugar, and vegetable oil as well as fertilisers. Later on, less restrictive measures (e.g. licensing requirements) were added, and a greater range of commodities was covered. While some of the early bans were removed or replaced with less restrictive measures, export bans remain the most used form of restriction so far (WTO, 2023).

[2] Ongoing work by the OECD is exploring the potential for trade liberalisation to mitigate the effects of extreme weather events on food availability and prices.

Table 2.1. Export restrictions on agri-food products during three recent crises

	Food price crisis (2008)		COVID-19 (2020)		Russian invasion of Ukraine (2022)	
	Number of countries	Share in world market of calories	Number of countries	Share in world market of calories	Number of countries	Share in world market of calories
Announcement			2	0.12%		
Ban	27	12.24%	22	7.97%	26	8.99%
Export licensing	3	0.05%	6	0.17%	9	2.89%
Not binding			1	1.52%		
Export taxes	9	6.39%			3	5.42%
Grand total	33	18.69%	25	9.78%	29	17.30%

Source: IFPRI Food and Fertilizers Export Restriction Tracker (Laborde Debucquet and Mamun, 2022), available at https://www.ifpri.org/project/covid-19-food-trade-policy-tracker (accessed 14 September 2022).

In addition to such disruptive trade policies, the effectiveness of global markets is also hindered by uncertainty over market conditions such as harvests, stocks, and policies in major exporting and importing countries. The G20-led Agricultural Market Information System (AMIS, www.amis-outlook.org) enhances transparency in global markets by disseminating timely information on market conditions and policies for major crops (wheat, maize, rice and soybeans).

2.3. Market structure and concentration

The structure of networks is an important determinant of resilience. In transport networks, bottlenecks such as a single bridge over a river or a single tunnel under a mountain range can lead to significant traffic problems when blocked, while a network with redundancy (several possible paths between two locations) will be less vulnerable to blockages on any specific path (Newman, 2018). Some of these intuitive insights also carry over to economic networks: the structure of input-output linkages between sectors can influence how an economy responds to shocks to particular sectors (Acemoglu et al., 2016; Carvalho et al., 2021). Similarly, market structure matters: all else equal, an economy where a small number of firms account for a large share of total output is more sensitive to idiosyncratic shocks affecting those firms (Gabaix, 2011).

In food supply chains, millions of farmers are connected to millions of consumers through a much smaller number of intermediaries (Deconinck, 2021). Agricultural input industries, too, tend to be concentrated (Fuglie et al., 2011; OECD, 2018; Hernandez and Torero, 2013). Moreover, as economies develop, important structural changes take place in the organisation of food supply chains, which evolve from traditional systems based around rural home production with little processing and short supply chains, through a transitional stage with growing urbanisation, rural-urban linkages, and widespread activity by small businesses (e.g. street vendors, urban wholesalers, vendors in wet markets) towards more modern supply chains characterised by fewer and larger firms active in retail and food service, food processing, and distribution (Barrett et al., 2021; Macchiavello et al., 2022). These modern supply chains also feature foreign direct investment by multinationals, and a growing importance of international trade and global value chains. The trends are related, as large multinational firms often act as lead firms in supply chains, coordinating operations and incentives (Swinnen and Maertens, 2007). The increased complexity of these supply chains is managed through greater vertical coordination along the chain using private governance mechanisms. This sometimes takes the form of outright vertical integration (e.g. when firms acquire their suppliers), but more commonly it relies on various instruments such as private quality standards, assurance schemes, and contracts to ensure quality and food safety attributes (Beghin et al., 2015; Barrett et al., 2021; Swinnen et al., 2015; Sexton, 2013).

These structural changes raise important questions about market power and welfare, for example the potential for large firms to raise prices to consumers, reduce prices paid to suppliers, and/or slow down innovation (Macchiavello et al., 2022; Crespi and MacDonald, 2022; see also Deconinck 2021; OECD 2014a, 2018; Howard 2016; Saitone and Sexton 2017; Sheldon 2017; Bonanno et al. 2018).

These questions are important, but conceptually distinct from the possible resilience effects of market structure and concentration. For example, a large multinational might simultaneously have more market

power and better opportunities to diversify its supply chains compared to a smaller firm. In some cases, concentrated markets with only a small number of firms may indeed be more vulnerable to disruptions; in other cases, the opposite may be true, as only large firms may have sufficient scale and access to finance to invest in resilient supply chains (including through the sourcing of supplies from a wide range of locations).

One case where market concentration has been mentioned as a possible factor leading to lower resilience is in the meat processing sector. As is discussed in Section 3.1.4, meat supply chains were heavily disrupted in early 2020, caused by the closure of many slaughterhouses in response to COVID-19 outbreaks. However, it is unclear whether high levels of concentration in processing capacity worsened these impacts (Ma and Lusk, 2021; Bina et al., 2022; Padilla et al., 2021).

On the other hand, investing in resilient supply chains is costly (e.g. the time and effort required to search, select and contract with several suppliers rather than a single supplier), and it is likely that larger firms will find it easier to bear these costs. For example, the Texas-based retailer H-E-B proved resilient during the early months of COVID-19 thanks to its extensive investments in emergency preparedness. The retailer employs a full-time director of emergency preparedness and had first developed contingency plans for pandemics in 2005 in the wake of an H5N1 bird flu outbreak in the People's Republic of China (hereafter "China"). Through its global sourcing network, the firm received reports on how COVID-19 was affecting the Chinese economy; this early warning allowed the firm to start taking a closer look at contingency planning already in the second week of January 2020. In meeting increased demand, the retailer also benefited from owning its own meat processing plant, which started running non-stop while reducing the number of products from several hundreds to just the fifty most popular items (Texas Monthly, 2020). It is unlikely that a small firm would be able to undertake these investments, or achieve this kind of coordination in its supply chain.

This example suggests that large firms in modern supply chains have the ability and incentives to invest in resilience, even if the private sector may not necessarily invest as much as the public interest would require (Baldwin and Freeman, 2022).[3] The example also suggests that features of modern supply chains, such as vertical coordination, can help build resilience.

Large retailers have also been instrumental in introducing stricter food safety and quality standards, which may help to reduce some risks such as food safety shocks (Beghin et al., 2015; Reardon and Timmer, 2012; Crespi and MacDonald, 2022).

In addition to static measures of market concentration, another important dimension of the structure of a market is its dynamism. Stimulating the process of creative destruction is essential to economic growth (Aghion et al., 2021). Some degree of failure (of business strategies, investments, or entire firms) is inevitable in a dynamic market, and even necessary: the absence of failure could indicate that market participants are no longer undertaking risky new projects such as investments in innovation, or that there is very little competitive pressure. While individual projects and companies may fail, the market as a whole benefits from this process through a higher rate of innovation. Arguably, the same processes are important for building system-wide resilience as well. To the extent that consumers value reliability, the competitive process will favour firms which invest in the resilience of their supply chains over firms which neglect to do so. While individual firms may thus fail, what matters is the overall resilience of the sector; and some degree of individual failure may simply reflect the "creative destruction" of less resilient business models by more resilient ones, which may strengthen overall resilience in the long run. Firms and markets may thus be able to deal with many risks on their own.

Governments may thus have an important role to play along two different dimensions: first, to facilitate competition in agro-food markets, and second, to assist in dealing with risks which exceed the capacity of the private sector, in providing public goods such as high-quality infrastructure or early warning systems, and in coordinating stakeholders (OECD, 2020b).

The importance of dynamism also suggests that statistical indicators of resilience based on market structure or the structure of supply chain networks may underestimate true resilience. For example, during the early months of COVID-19, the French retailer Carrefour faced a disruption of its Indian supplies of

[3] OECD (2017) made a similar argument about the role of agro-food companies in responding to agriculture water risks due to potential reputational damage.

rice, but quickly contracted with suppliers in Pakistan (OECD, 2020a). An analysis of existing or historical supply chain relationships cannot easily capture the possibility of creating new patterns when needed.

2.4. Just-in-time supply chain management and safety stocks

Just-in-time supply chain management is based on the idea that inventory at different stages of the supply chain or production process should be kept as low as possible, and material should be "pulled" from one stage to the next only as needed. This reduces costs related to holding inventory, but importantly it also helps reduce the cost of defects (by allowing earlier detection and faster response) and removes unnecessary delays (Sheffi, 2021; Shah and Ward, 2003). Just-in-time practices are considered part of the "lean" approach to production, which also includes quality control, continuous improvement, and specific human resource processes (Shah and Ward, 2003). These ideas are often traced back to practices introduced by Toyota in Japan in the 1960s (Hopp and Spearman, 2021).

Some observers have argued that just-in-time supply chain management approaches were to blame for supply chain disruptions following COVID-19 (Sheffi, 2021). In this interpretation of events, low inventories made global supply chains fragile, and if companies had held greater inventories "just-in-case", disruptions could have been avoided or reduced. Studies of past volatility in agricultural commodity prices have similarly highlighted the importance of the stocks-to-use ratio (Bobenrieth et al., 2013; Baffes and Haniotis, 2016).

Yet, as Sheffi (2021) points out, the just-in-time approach also creates greater flexibility and responsiveness for firms, exactly because there is less pre-committed inventory in the system. Just-in-time approaches also require close co-ordination and communication between different supply chain actors, which in turn makes it easier to adjust in response to shocks.[4] Sheffi (2021) also notes that the magnitude of the disruptions in the past two years means that even sizeable safety stocks would have merely delayed problems, rather than prevent them.

There is a paucity of comprehensive data on how widespread just-in-time approaches are in food supply chains relative to other sectors of the economy, but the available evidence suggests a more limited uptake compared to the manufacturing sector (Panwar et al., 2015, Dora et al., 2013). During the initial months of 2020, firms along food supply chains did rely in part on safety stocks to buffer the disruptions to supply and demand (OECD, 2020a). Given the seasonality of agricultural production, a higher level of stocks could be expected relative to other sectors. Hence, it is not clear to what extent just-in-time supply chain management affects food supply chain resilience today.

The question of inventories and safety stocks is also related to the role of public stockholding. There are three major types of public stocks (Deuss, 2015):

- *Emergency stocks* are held for use in humanitarian emergencies (e.g. caused by natural disasters).
- *Social safety net stocks* distribute food at subsidised prices to help food insecure households.
- *Buffer stocks* aim to protect producers from sudden drops in producer prices and/or protect consumers from sudden consumer price spikes.

While the use of emergency stocks for humanitarian emergencies is widespread, social safety net stocks and buffer stocks are more commonly found in low- and middle-income countries. Social safety net stock schemes are more akin to food assistance programmes: their performance depends on having well-defined objectives and effective targeting, and should be compared with other possible instruments, including providing income support or building a broader social safety net. Buffer stocks, by contrast, aim to buy and sell in order to influence market prices. It is not clear whether buffer stocks actually reduce domestic price volatility, and even if they do, it is at a high cost. First, these schemes are almost always implemented through other policy instruments such as price regulations, trade restrictions, and import and export monopolies, creating economic inefficiencies. Second, even though these schemes in theory should buy

[4] Smaller batch sizes, shorter lead times, and better co-ordination among supply chain actors also help reduce the so-called "bullwhip effect", the phenomenon whereby variability of orders increases as one moves upstream in a supply chain (Wang and Disney, 2016).

low and sell high, this often does not work and countries end up with a fiscal deficit and/or excessively large stocks. Third, the accumulation and release of stocks can create instability in global markets (Deuss, 2015).

3. Shocks and resilience in food supply chains

3.1. Evidence on risks and resilience in food supply chains

To better understand risks and resilience in food supply chains, this section reviews the evidence on historical shocks and their impacts on a range of food supply chains. The focus here is on shocks that may cause large, widespread, or long-lasting effects on food supply chains. Among the possible sources of shocks, five categories were identified (following Rosales 2015; Zhao et al., 2020 and Davis, 2021). The risks and their impacts are discussed in more detail below; Table 3.1 summarises the main findings. Many of these shocks are becoming more frequent and/or more severe due to climate change. This is the case for extreme weather events such as droughts, floods or heatwaves (which can disrupt agricultural production, as well as transportation), but climate change may also exacerbate some of the other risk factors, including increased pests and animal diseases and food safety risks (due to an increased prevalence of pathogens) (IPCC, 2022).

Table 3.1. A typology of food supply chain risks and their implications for systemwide resilience

Risk	Examples	Effects	Extent	Severity	Period
Extreme events	Droughts Landslides Earthquakes Tidal waves	**Consumption** Price increases Stock-outs **Production** Lower yields Production losses Distribution	Local to regional	Low to medium	Short to medium term
Pests and animal diseases	Foot and Mouth Disease African Swine Fever	**Consumption** Impacts limited **Production** Production losses, culling of animals, trade bans	Local to regional	Low to medium	Short to medium term
Food safety shocks	Mad Cow Disease (BSE) NZ milk scare 2013 (Botulism) Melamine in milk powder (China 2008)	**Consumption** Quality Stock-outs **Production** Input supplies Production losses Distribution	Local to regional	Low to medium	Short to medium term
Socio-economic systems	Human pandemics Civil/regional conflict Policies that affect distribution Food 'runs' (stockpiling)	**Consumption** Stock-outs Price increases **Production** Input supplies Harvesting Distribution Processing	Local to global	Low to high	Short to long term

Risk	Examples	Effects	Extent	Severity	Period
	Input shocks, e.g. fuel prices, fertiliser prices Labour market shocks (e.g. strikes, isolation requirements for COVID)				
Trade restrictions	Trade sanctions Trade wars Restrictive trading rules	**Consumption** Stock-outs Price increases **Production** Input supplies Distribution	Regional or bilateral	Low to high	Medium to long term

Source: OECD analysis; see main text for detailed discussion. Local extent here means at the national or sub-national scale; regional extent means affecting several countries in the same region. Low severity refers to impacts that are barely distinguishable from normal variability, while high severity refers to a significant increase in acute food insecurity in the affected region. Short term is defined as one year or less; medium term is defined as between one and five years; long term is defined as more than five years.

3.1.1. Extreme events

Droughts are relatively common, and involve prolonged shortages of atmospheric, surface or groundwater, that impact crop yields and livestock carrying capacity. Droughts directly affect producers and supply chains and can severely impact food supply chains when they disrupt a large proportion of domestic or global food production (e.g. droughts impacting major grain growing regions). This can have implications for domestic and global food prices and food security (OECD, 2017), particularly for lower income groups (Quiggin, 2007). Increased prices for wheat, corn, and other grains often also lead to higher prices in other food sectors, such as livestock and processed foods. Global food supply chains are generally able to respond to droughts as these rarely impact all important growing regions at once.[5] However, the global impact of a drought is larger if it affects a major growing region (OECD, 2017). In 2012, a historic drought in the US Midwest led to a reduction in US maize production by 13% compared to the previous year, with major repercussions for global markets as the United States typically accounts for some 40% of global maize production (USDA, 2013).

In the short run, higher prices lead to a reorientation of supplies globally, while private trading firms may draw down stocks. Substitution may take place on the demand side (e.g. replacing corn with other coarse grains for animal feed). For cereals, high prices may in turn stimulate increased planting in other regions with complementary growing seasons (e.g. in opposing hemispheres) or for crops with multiple intra-annual growing seasons (e.g. summer and winter wheat varieties and rice production). This reduces overall price shocks for consumers in the medium term. But temporary price increases and shortages in important food products may have food security implications, especially for lower income cohorts in the countries affected by drought or in import-reliant countries (Ruel et al., 2010; Davis et al., 2021).[6]

[5] There is some concern that climate change may create synchronous harvest failures; however, to date there is little evidence of this (IPCC, 2022).

[6] Recent work by OECD has investigated how the agricultural sector in Türkiye (Bagherzadeh and Shigemitsu, 2021) and in Italy (Baldwin and Casalini, 2021) can be made more resilient to droughts.

Other extreme events include other extreme weather events and natural disasters such as earthquakes or major storms. Some recent examples include the coffee frost in Brazil, Hurricane Ida in the United States, extreme rainfall and floods in Western Europe and Henan (China), or typhoons in Japan.[7] The implications of these events are similar – significant reductions in local production that can disrupt domestic and international food supply chains. As outlined in the review by Davis et al. (2021), extreme events may impact downstream supply chain activities. Typically, these events are concentrated in local or domestic supply chains. Effects often include stock outs, food "runs", and price increases, which can have implications on local food security and nutrition. Effective local and domestic disaster relief mitigate these effects, especially for lower income groups (e.g. Rose et al., 2011). Extreme events will have more serious impacts to domestic or global food supply chains where the events impact "bottlenecks" within the supply chain, for example logistics hubs and processing facilities (Jones and Hillier, 2017).

Policy responses to droughts and other extreme events can magnify or redistribute impacts. For example, during the flash drought in Russia in 2010, the Russian Government banned the export of wheat in early August 2010 to protect domestic prices and consumption. This led to increases in wheat prices globally (Hunt et al., 2021). The role of such trade restrictions is discussed in more detail below.

3.1.2. Pests and animal diseases

A wide range of pests and animal diseases can affect food supply chains. Many countries maintain lists of notifiable diseases, for which suspected cases need to be reported to public authorities.[8] The discussion here is therefore by no means exhaustive, but focuses on three high-profile cases.

Foot-and-mouth disease (FMD) is a highly contagious viral disease that can affect cows, pigs, sheep, goats, and deer, among others. While most OECD countries are FMD free, occasional outbreaks have occurred in the United Kingdom (2001 and 2007), Japan and Korea (2011), and Türkiye. FMD outbreaks are often controlled by large animal culls in impacted regions, resulting in price increases and consumers shifting to other products (e.g. imported products or other meat products). While FMD remains a pathogen of concern for OECD countries, outbreaks are quickly identified and have been effectively controlled in recent years. Control measures, managed by the International Animal Health Organisation (OIE), help mitigate the consequences of stock culls and trade bans (Junker et al., 2009).

African Swine Fever (ASF) is a highly contagious viral disease affecting domestic and wild pigs. Control measures in affected countries include culling animals, zoning and surveillance. A few minor outbreaks have occurred in European countries, although the 2018-2020 ASF outbreak in China has been more significant given that China is both the largest producer and consumer of pig meat globally. Frezal et al. (2021) estimated that the outbreak in China would result in a 27% drop in the production of pig meat, while Chinese consumers would shift consumption to other meat products and pig meat imports, leading to a 9% increase in global pig meat prices. These impacts were only short term as production and consumer preferences returned to pre-outbreak levels soon after. The ASF outbreak in China also had spill over impacts on other food supply chains. For example, the ASF outbreak saw large changes in export flows of animal feed products such as canola, barley and corn from Australia, Canada, and other OECD member countries (Pitts and Whitnall, 2019).

Avian influenza, also known as bird flu, is a family of respiratory diseases which affect poultry but which can be passed on to humans. Most avian influenza viruses are of low pathogenicity, but highly pathogenic avian influenza viruses can have major consequences. The 2014-15 outbreak in the United States remains the largest in an OECD country. The disease spread through 21 states and resulted in a loss of approximately 7.5 million turkeys and 42.1 million laying hens through infection or culling to control the virus. While production generally returns to pre-outbreak levels quickly due to fast reproductive rates of poultry, Avian influenza outbreaks can result in significant bird losses, resulting in temporary price increases and stock outs for egg and poultry meat products. For example, egg prices increased by 61%

[7] Recent work by OECD discusses options to strengthen the agricultural sector's resilience to typhoons and heavy rain in Japan (Shigemitsu and Grey, 2021) and to floods in the United States (Grey and Baldwin, 2021) and New Zealand (Casalini et al., 2021).

[8] A list of notifiable diseases is maintained by the World Animal Health Organisation, see https://www.woah.org/en/what-we-do/animal-health-and-welfare/animal-diseases/ (accessed 28 June 2023).

over the 2014-15 US outbreak period due to inelastic demand for egg products and reduced supply as the flock of egg-laying hens fell by 12% (Ramos et al., 2017). Producers are directly impacted by outbreaks (loss of stock) and loss of export markets, but some benefit from higher prices: for example, in the 2014-15 outbreak, aggregate revenues of the egg industry increased (Ramos et al., 2017). However, this is not universal: during the same outbreak, industry revenues for broiler (meat) chickens fell as the loss of export opportunities led to lower prices, while the flock size was essentially unchanged (Ramos et al., 2017, MacLachlan et al., 2021).

For consumers, impacts of animal disease events have generally been relatively limited. Surveillance and import standards typically keep health risks low, although monitoring is essential to identify and prevent any possible human-to-human spread.[9] During outbreaks consumers are usually able to shift to substitutes, which helps to maintain food intake, but may not offset food price increases associated with disease events as rising demand for substitutes also puts upward pressure on their prices.

3.1.3. Food safety shocks

Food safety incidents are relatively common occurrences. These include pathogen outbreaks (e.g. salmonella) and contamination of food products with allergens, heavy metals, or other harmful substances. A review found 8 914 reported food safety incidents globally between 2008-2018 (Soon et al., 2020). Even if individual incidents often have only limited effects on human health, especially in OECD countries, food safety is a major concern globally: foodborne diseases caused an estimated 420 000 premature deaths in 2010, mostly concentrated in low- and middle-income countries in Asia and Sub-Saharan Africa (Jaffee et al., 2019). The discussion in this section focuses on food safety incidents' impact on the functioning of supply chains, rather than their direct effects on human health.

Mad cow disease (Bovine Spongiform Encephalopathy, BSE) is linked to a fatal disease affecting humans, called variant Creutzfeldt-Jakob Disease (vCJD). Since 1996, 231 cases of vCJD have been reported globally; human health risks appear limited in part because the spread of BSE to humans does not seem to be common (CDC, 2021). In response to BSE outbreaks, many countries imposed import restrictions on beef from impacted countries. Consumers in outbreak countries also shifted away from beef, an effect which persisted (Pritchett et al., 2005). Long-term reductions in beef demand approached 25% of their original value in Europe (Thomson and Tallard, 2003). Trade restrictions between the EU and British beef lasted ten years until 2006, while Japan gradually removed remaining import restrictions between 2019 and 2023. Restrictions and changes in demand negatively affect domestic producers in outbreak areas. The US Food and Drug Administration (FDA) estimated a 24% decline in domestic beef sales and an 80% decline in cattle exports if a US outbreak were to occur (Mathews et al., 2006).

A **contamination of milk and infant formula with melamine** was discovered in China in 2008. Reports indicated an estimated 294 000 victims (mostly infants), with 54 000 hospitalisations (Branigan, 2008). Purchases of milk products from impacted processors in China fell by over 80%. Consumers substituted to other products, including milk powder and imports (Qian et al., 2012). Stock prices for affected Chinese dairy producers fell by more than 40%. Chinese dairy farmers were forced to dump milk, resulting in lost revenue and longer-term stock reductions in dairy cattle. Consumers changed consumption patterns, with many switching to imported products and milk powder at slightly higher prices (Qian et al., 2012).

In 2017, an **outbreak of listeriosis** was reported on deli meat commonly referred to as "polony" in South Africa. It took over a year to identify the source of the outbreak, and in 2018 a recall was announced. In total, 1 034 cases of listeria were identified, with 204 confirmed deaths. During the outbreak period, there was a 50% drop in consumer demand for pork and a 40% reduction in producer prices. Export impacts were relatively minor due to the small export market for South African processed meats (Olanya et al., 2019).

Following a **suspected contamination of dairy products with botulism** in New Zealand, the Fonterra company recalled three batches of product. Eventually, it became clear that this was a false alarm. The event was disruptive as the suspect batches had been used in multiple products, including baby formula (Stojkov et al., 2018). A number of countries introduced total import bans on New Zealand dairy products.

[9] More generally, the spread and impact of pests and animal diseases is reduced by animal health regulations and other public policies (OECD, 2012). For a historical perspective, see Olmstead (2009).

There was a persistent negative impact on whey products and infant formula trade, although this was mitigated by increased trade in other milk products (Stojkov et al., 2018). Consumers in New Zealand and overseas were able to shift consumption to other products.

These cases all concerned high-profile incidents, which are rare relative to more limited food recall events. Analysing all meat recalls in the United States between 2007 and 2017, Yim and Katare (2023) find small reductions in meat purchases which disappear within one to three weeks after the recall announcement. Some studies find modest effects even for major food scares: Rieger et al. (2016) find that the 2011 dioxin scandal in Germany had only a limited effect on consumption patterns, and Ishida et al. (2016) find that the effect of the 2004 outbreak of H5N1 bird flu on Japanese meat consumption was smaller and shorter-lived than that of the BSE crisis.

3.1.4. Socio-economic systems

Food supply chains are embedded within broader socio-economic systems, and are hence vulnerable to a wide range of shocks originating in other economic sectors or deriving from broader events.

Input shortages or price shocks in production or downstream supply chain activities can lead to shortages and price shocks for food products. Key inputs include fuel, fertilisers, and cargo shipping. Aviation may also be a key logistics input for high value products. Examples of input shocks include the fuel and fertiliser price shocks in 2007-08, shipping container and air freight shortages in 2020, and fertiliser shortages and export restrictions from China and Russia in 2021-22. Shocks to key inputs, and fuel in particular, are often cited as a key risk in food supply chains. Fuel price shocks can in turn impact the price of fertiliser and logistics, and increase the diversion of food to biofuel production. But price shocks to fuel and fertiliser frequently coincide with trade restrictions, speculation, and macroeconomic pressures. For this reason, it is not clear whether fuel prices by themselves cause higher agricultural commodity prices, or whether both are instead caused by common factors (Baumeister and Kilian, 2014). In high-income countries, where agricultural commodity prices account for only a small share of the final retail price, commodity price increases in turn have only a limited effect on consumer prices, although this link is more pronounced in developing countries (Baumeister and Kilian, 2014). Poor households are particularly vulnerable to these price shocks, which can have significant adverse impacts on household budgets and overall calorie and nutritional consumption (IFPRI, 2011; Ruel et al., 2010).

Logistics disruptions are a related type of shock; these can cause shocks in food supply chains, especially when they occur at key chokepoints within logistics channels. These shocks can be local or regional in nature (e.g. disruptions to key rail or road networks) or can be global when impacting key maritime or air routes. Logistics shocks may occur due to climatic or natural disaster events, or human-made disruptions such as sudden port closures or terrorism and other infrastructure damage. A recent example impacting global trade was the Ever-Given Suez Canal blockage in 2021. Estimates of the impacts of the Suez Canal disruption vary, but it is estimated that some products faced short term shortages and price increases, including oil to Europe (Lee et al., 2021). Previous analysis has indicated key risks associated with prolonged closures of particular maritime chokepoints, with some countries and crops more vulnerable than others (Wellesley et al., 2017). For example, soybean and wheat trade would be significantly impacted by prolonged closures of the Panama Canal and Turkish straits, respectively. Countries located in the Mediterranean are also vulnerable to a number of maritime chokepoints such as the Suez Canal and Straits of Gibraltar.

The **2007-08 global food crisis** is an example of a crisis where several shocks coincided. During this crisis, the world saw significant increases in food prices, in particular for staple foods such as rice and wheat, as well as for corn and soy. A number of factors contributed to the price increases (Heady and Fan, 2008). These include rising prices of oil, fertilisers, and shipping, increased biofuel production, droughts in major producing countries, a depreciation of the US dollar (which tends to increase prices of commodities traded in dollars), and trade restrictions. Average food commodity prices more than doubled between 2005 to their peak in mid-2008 (Gilbert, 2010). Higher average prices persisted across a number of staple foods, with this price transmitting to other food groups and domestic markets (Heady, 2011).

High world food prices had significant distributional consequences for food security and poverty, especially in the developing world, where higher prices raised the cost of food budgets for poorer households, especially in countries reliant on imports. At the same time, higher food prices may also raise the incomes of those working in agriculture. Effects may therefore differ between urban and rural populations (Heady

and Martin, 2016; Verpoorten et al., 2013). Policy responses to the 2007-08 food price crisis were ad hoc in nature, and in some cases counterproductive at a global level, e.g. through export restrictions (discussed in more detail below) (Heady, 2011). The rapid onset of price increases exposed underlying deficiencies in available information of agricultural markets, contributing to poorly informed policy responses. Measures to increase market transparency since the 2007-08 food crisis, such as the creation of the Agricultural Market Information System (AMIS), have contributed to greater food market resilience during the COVID-19 pandemic (OECD, 2020c).

The COVID-19 pandemic, and the various public health measures and other policy responses, created unprecedented pressures on food supply chains, through many channels (OECD, 2020a). These included:

- Labour shortages along the supply chain, due to lockdowns and reduced labour mobility (e.g. a shortage of migrant workers).
- Delays and shortages in supply chains, due to outbreaks in processing and distribution bottlenecks and reduced availability of intermediate inputs.
- Unprecedented shifts in demand, as demand for "food away from home" (restaurants, canteens) collapsed while retail demand surged.
- Disruptions in international trade due to e.g. export restrictions, border controls, and reduced air travel (which reduced the available air cargo capacity in the "belly" of passenger planes).

The drastic shift in demand in particular stands out, as other shocks have not involved shifts of such magnitude. In the span of two weeks (between 10 and 24 March 2020), restaurant reservations in high-income countries fell to zero. In the same period, food purchases in supermarkets soared: in the second half of March, weekly sales of frozen foods in France were 63% higher than the year before; sales of packaged foods in Germany were 56% higher year-on-year; and similar spikes were seen in other countries. After this initial spike, retail demand for fresh, frozen or packaged foods remained about 15-20% higher than usual for several months (OECD, 2020a). Consumers typically purchase different foods in restaurants than they would purchase in supermarkets (e.g. steaks versus minced meat); moreover, packaging sizes in retail are much smaller. Adapting to the demand shift thus required a major reorientation of food supply chains.

Another notable food supply chain disruption during the pandemic was the closure of many slaughterhouses due to COVID-19 outbreaks. In the United States, for example, slaughter of cattle and pigs fell by 40% year-on-year in April 2020. These disruptions disconnected the primary production of livestock from the distribution and consumption stages, simultaneously creating temporary shortages for consumers while creating a build-up of unsold animals at the production stage. In many cases, these animals had to be euthanised to prevent overcrowding. While closures of slaughterhouses occurred in many countries, the disruption of the livestock and meat supply chain was particularly pronounced in the United States. It has been argued that the disruption may in part be due to the high levels of concentration in the sector. For example, 60% of US pork processing capacity comes from just 15 plants (OECD, 2020a; Lusk et al., 2021). However, the link between resilience and concentration is disputed: Bina et al. (2022) found that within the United States, regional disruptions in beef markets were unrelated to dependence on larger processing facilities, and Padilla et al. (2021) similarly report that US regions with larger plants did not have greater disruptions in hog slaughter rates. Simulations also suggest that less concentrated market structures would not necessarily have superior resilience (Ma and Lusk, 2021).[10]

Despite initial disruptions, food supply chains in OECD countries showed a remarkable resilience, and shortages disappeared over time. This relative resilience was driven by coordination among supply chain actors, innovation and greater use of new technologies (e.g. click-and-collect), and rapid policy responses by government. These policy responses moreover avoided some of the mistakes made during the 2007-2012 food price crises (Gruère and Brooks, 2021; OECD, 2020a, 2020c; OECD, 2021d). Average gross

[10] One reason has to do with the laws of probability. If each firm has e.g. a 30% chance of shutdown, then an industry with many equally-sized firms will on average see 30% of firms shut down, leading to an output reduction of about 30%. By contrast, in a heavily concentrated industry, the range of possible outcomes is wider. In the extreme case with only a single firm, for example, there would be a 30% chance of a 100% drop in output, and a 70% chance of no disruption (Ma and Lusk, 2021).

farm receipts for OECD and emerging economies increased in 2020, and the sector was the best performing or least affected economically in several countries. The greatest impact was arguably due to the economic impact of COVID-19 on consumers' incomes: food insecurity increased among people who lost their livelihoods due to COVID-19 restrictions (OECD, 2021a).

Compared with the other types of shocks reviewed here, shocks originating in socio-economic systems come with a wider uncertainty range: their impacts vary in extent (from local to global), severity (from low to high), and duration (from short to long term).

3.1.5. Trade restrictions

As noted above, **export restrictions** are often used in response to agro-food commodity price increases. Several countries imposed export restrictions during the commodity price increases in 2006-08 and 2010-11. They were also used, although to a lesser extent, during the COVID-19 pandemic (FAO, 2021a) and following the Russian aggression against Ukraine (Laborde Debucquet and Mamun, 2022).

In 2006-08, when food prices were increasing rapidly, several major grain exporting countries adopted export restrictions or bans. Some importing countries reacted by reducing pre-existing import restrictions such as tariffs (Jones and Kwiecinski, 2010). The result was additional upward pressure on world prices. Some 45% of the increase in international rice prices in 2006-8, and almost 30% of the increase in international wheat prices, was likely due to these kinds of trade policy responses, rather than initial market conditions (Martin and Anderson, 2012). Export restrictions are a "beggar-thy-neighbour" policy, as they can at best stabilise prices domestically by increasing pressures on global markets (Martin and Anderson, 2011; Deuss 2017). While export restrictions appear to have stabilised domestic prices in some contexts (Abbott, 2011), interventions often do not even achieve this goal (Jayne and Tschirley, 2009). Moreover, as other countries respond with trade interventions, the net effect on domestic price instability is limited (Anderson and Nelgen, 2012).

Import restrictions include tariffs, quotas and other measures explicitly designed to restrict the import of certain products, as well as other measures which may indirectly restrict imports (e.g. sanitary and phytosanitary requirements). Import restrictions may be imposed due to food safety concerns (e.g. disease and pest outbreaks in exporting countries), or to protect domestic producers from foreign competition. Import restrictions may be imposed for reasons unrelated to food supply chains, for example in the context of a trade war. Tariff and import restriction shocks have immediate impacts for producers in exporting countries through lost markets. World prices may also fall if the imposing country is a major importer (OECD, 2019a). Recent evidence suggests that the impacts from tariff shocks on exporters dissipate relatively quickly, as producers and other supply chain actors find new markets and adjust production (e.g. Adjemian et al., 2021; Cao and Greenville, 2021). Although tariffs are designed to help domestic producers, the same policies tend to have a negative impact on the food security of poor households by increasing prices for staple foods.

3.2. Food supply chain resilience to shocks: Common findings

The review of food supply chain shocks above covers a wide range of shocks, from trade policy shocks to outbreaks of livestock diseases and extreme weather events. In addition to the specific effects discussed above, some common insights can be derived.

3.2.1. Temporary price increases appear to be the most common impact

First, for most of the shocks mentioned above the main impact is higher food prices, which disproportionately affect lower-income households. It is rare that a food supply chain shock results in serious shortfalls in overall food availability.

Food price increases appear to last anywhere from one to five years, but major price rises are usually contained to relatively short periods of time. In general, agricultural commodity prices have resumed a downward trend following sudden price increases (OECD, 2021b). In severe cases, initial price shocks may be compounded by other shocks occurring at the same time (e.g. fuel price increases, or employment and income losses) and by the responses of private actors (e.g. speculation, stockpiling) and public organisations (e.g. export restrictions) (Tadasse et al., 2016). Food price rises are felt by virtually all

consumers, but disproportionately affect poorer consumers. In developing countries, food price increases particularly affect the urban poor (Ruel et al., 2010).

While high food prices impose hardship on poor consumers, high prices are an important market signal that stimulate supply chain actors to increase supplies in response to the supply shortfalls created by various shocks. Given that lower income households are most affected by price increases, the most effective response may be to provide a social safety net and financial or food assistance.

3.2.2. More evidence is needed on the role of market concentration and just-in-time approaches

A second finding is that there is at present limited conclusive empirical evidence on the role of market concentration and just-in-time approaches on resilience.

As noted earlier, more concentrated markets could in principle be more vulnerable to shocks, and high levels of concentration in meat processing possibly exacerbated the effects of COVID-19-induced closures. At the same time, larger firms may also be better placed to invest in resilience and to take the lead in coordinating supply chain actors. While the link between market concentration and resilience is much discussed, at present there is little empirical evidence (Hadachek et al., 2023).[11]

Similarly, while just-in-time supply chain approaches have been criticised as a possible source of fragility in food supply chains, there is currently little conclusive empirical evidence on this question; the review of shocks did not uncover any obvious cases where just-in-time approaches undermined resilience.

3.2.3. Government responses can help, but have often been counterproductive

Well-designed policy responses can enhance the resilience of food supply chains and systems. For example, short-term financial assistance to poorer households or food assistance programmes can reduce food insecurity without disrupting the functioning of markets. During COVID-19, governments also responded with initiatives to ensure the smooth functioning of supply chains, e.g. by removing bottlenecks at the border (OECD, 2020a). The impact of pests and animal diseases on food systems is also reduced through government policy (OECD, 2012). However, government responses to some food system shocks have tended to impede adjustment and undermine resilience. Sudden trade restrictions in particular appear both popular and harmful, as noted above.

Yet, openness to trade is not necessarily sufficient to deal with severe shocks, and additional mechanisms are needed to manage such risks. Work by the OECD has identified four “Keys to resilient supply chains” (Box 3.1). The review here shows that these keys are all highly relevant to resilience in food supply chains. Importantly, this work highlights that an effective approach should look at possible risks along the whole supply chain, not merely its international aspects; and that governments should not try to handle all risks, only those risks which are too big for private actors to handle alone (see also OECD 2011 and 2021f). Government efforts to improve responsible business conduct (RBC) in value chains can also help in strengthening the resilience of these value chains (OECD, 2021e). The question of optimal government policy to strengthen resilience is discussed further in the concluding section.

[11] Assessing the role of market concentration on resilience may be complicated since market concentration is rarely exogenous, but itself shaped by various factors (e.g. economies of scale, technical features of the underlying technologies, the regulatory environment) which could independently affect resilience. For similar reasons, assessing the impact of market concentration on other outcomes such as prices or innovation requires careful economic modelling, and superficial correlations can be misleading (Deconinck, 2021).

Box 3.1. Keys to resilient supply chains

Work by OECD has identified four "keys to resilient supply chains". To build greater preparedness and responsiveness, policy makers should (1) anticipate risks; (2) minimise exposure; (3) build trust; and (4) keep markets open. For each of these tasks, detailed recommendations have been developed.

To anticipate risks, governments should (among other activities) develop risk management strategies for essential supply chains, covering not only international aspects but the whole value chain. Not all risks require government intervention; governments should focus on the most severe types of risks which are beyond the capacity of the private sector.

To minimise exposure, governments can proactively invest in better infrastructure and digital trade solutions, and provide regulatory flexibility. These actions improve productivity in addition to building greater resilience.

To build trust, it is essential to co-operate and co-ordinate among governments and between the public and private sector. This includes international cooperation to avoid "beggar thy neighbour" policies, as well as public-private action plans and other measures to boost confidence that supply chains will be able to keep functioning.

Finally, keeping markets open requires not only actions at the national level but also international cooperation. Governments should refrain from harmful policy choices such as panic buying or hoarding (e.g. through export restrictions), and should strive for transparency regarding supply conditions and policy developments. Trade facilitation measures help ensure the swift movement of goods across borders, and can be complemented with measures designed specifically for crises, such as fast clearance procedures or accelerated certification processes.

Source: OECD (2020), Keys to Resilient Supply Chains, https://www.oecd.org/trade/resilient-supply-chains/.

3.3. Limitations of the food supply chain lens

A large proportion of reviews in the literature focus on the resilience of *individual supply chains* rather than resilience of overall food supply. The distinction appears to be only occasionally made explicit. Often, it is implicitly assumed that findings for a specific supply chain can be extrapolated to make conclusions about overall resilience of food supply. However, this assumption is not warranted, for several reasons:

- Consumers in many cases are able to *substitute* other products to maintain their consumption needs.
- Industries and firms *compete* at least in part on the basis of resilience. Some degree of failure may be an inevitable by-product of the process of creative destruction (or trial-and-error) as firms seek to adapt their strategies.
- Temporary *price increases* are a common impact of food supply chain shocks, and are indeed undesirable from a food security point of view. Yet these price increases also stimulate firms to increase supplies in the market, and are therefore also an important mechanism through which markets and trade can help societies adapt to shocks.
- What is relevant for resilience of an individual supply chain (or an individual firm) is not necessarily relevant for the resilience of overall food supply, and vice versa.[12]

[12] Another limitation is that many studies focus on the role of shocks to agricultural commodities. However, post-farmgate processes and non-commodity inputs (e.g. labour, energy) account for a much larger share of food expenditures in middle- and high-income countries (Yi et al., 2021).

4. A broader food systems perspective on resilience

The discussion above suggests that analyses should look at the resilience of the overall food supply rather than (or in addition to) supply chain-specific studies. That said, this would still maintain a narrow focus on the physical availability of food. Such a perspective on resilience is insufficient for several reasons. First, food security is usually a problem of *access* to food rather than availability of food. A narrow focus on availability in supply chains therefore obscures other important aspects of resilience, and ignores important policy levers. Second, food systems provide a wider range of essential services. These include not only food security and nutrition, but also livelihoods to those working along food supply chains; and food systems are also expected to contribute to environmental sustainability and climate mitigation. Third, food systems themselves also create pressures which can undermine resilience in the longer term and also impact other domains. Effective policies should take into account these diverse objectives and feedback effects, and find ways to maximise synergies and minimise trade-offs when using policies to address shocks. This requires a more holistic view of the resilience of food systems.

4.1. Food security often depends on access rather than availability of food

Food security is commonly defined (following the 1996 World Food Summit) as a situation where "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." In line with this definition, food security is often conceptualised in terms of *availability* (physical supply of food), *access* (the ability of relevant groups to have access to available food, e.g. in terms of household income and affordability), and *utilisation* (which relates to consuming a safe and nutritious diet); complete food security then requires *stability* across these three dimensions.

Discussions on the resilience of food supply chains often implicitly narrow the food security question to an issue of availability. However, food insecurity is more commonly caused by problems related to access to food, especially poverty (Smith et al., 2000; Barrett and Lentz, 2017). This does not mean that the availability of food should be taken for granted: given population and income growth, the coming decades will see a steadily increasing demand for food, while productivity growth is being negatively affected by climate change (IPCC, 2022). Moreover, the dimensions of availability and access are not completely independent from each other either: because demand for food is typically inelastic, shocks to availability can easily inflate food prices (as noted earlier), which can reduce poor households' access to food. But the importance of access to food, in addition to its physical availability, implies that food security risks can and should be addressed using a wider range of policy levers than through food supply chain resilience alone.

While food prices receive much attention (particularly when prices are high and volatile, as is currently the case), household income remains a much more important driver of food (in)security. Where incomes are extremely low, even cheap food may be out of reach. In the early 2000s, when international food prices were at all-time lows, there were more than 800 million undernourished according to FAO estimates (FAO, 2022). By contrast, income growth typically leads to a decrease in childhood stunting, an indicator of chronic childhood malnutrition (Headey, 2013). Recent research has shown that the cost of a healthy and nutritious diet exceeds per capita income for at least 1.6 billion people, while this cost represents only a fraction of incomes in high-income countries. While the cost of a healthy and nutritious diet itself varies by country, the main driver of affordability is income (Hirvonen et al., 2019; Bai et al., 2021). Broad-based economic growth is thus a key factor in improving access to food. Effective and targeted social safety nets could similarly play an important role.

At the same time, conflict and civil strife can rapidly undermine access to food. Even before COVID-19, progress in reducing undernourishment had stalled or even gone into reverse, in part due to conflicts and internal displacement (FAO et al., 2017). Addressing food insecurity in these contexts is challenging, and requires efforts to restore peace, to provide humanitarian assistance in the short term, and invest in development for the long run. In 2019, the OECD Development Assistance Committee (DAC) adopted its Recommendation on the Humanitarian-Development-Peace Nexus, underscoring the importance of simultaneously working on these three dimensions to strengthen resilience in fragile contexts (OECD, 2022). Food assistance, under the terms of the 2012 UN Food Assistance Convention, is one possible

response to humanitarian emergencies. In general, the provision of financial assistance to buy food (an access-focused strategy) is preferable to physical food aid (an availability-focused strategy), including to promote the development of local markets.

Yet the problem of access to food is not confined to poor countries: food insecurity also exists in high-income countries (Giner and Placzek, 2022). While severe food insecurity is rare, FAO estimates that at least 7.5% of the OECD population suffered from moderate food insecurity over the 2018-2020 period. However, understanding the true extent of food insecurity in OECD countries is difficult in part because most OECD countries do not routinely measure food (in)security, and those who do rarely use internationally comparable methodologies and instruments. The available evidence shows that food insecurity is more common among households that include adults with disabilities, as well as single-parent households, especially single women with children. Some ethnic groups and Indigenous populations also face higher risks of food insecurity. More generally, low income is an important risk factor for food insecurity, as is unemployment, although the majority of food insecure households in OECD countries include an employed adult (Placzek, 2021).

COVID-19 increased the prevalence of food insecurity in OECD countries. In a survey conducted by OECD as part of the OECD COVID-19 and Well-being Report, 28% of respondents across 22 OECD countries said they had to compromise on the quality of their diets because of the crisis (OECD, 2021a). Food banks similarly reported an increase in demand for aid. While food supply chains in OECD countries were generally resilient during COVID-19, the crisis affected vulnerable population groups through lower incomes.

In OECD countries, responses to food insecurity typically focus on livelihood assistance (such as increasing universal social security payments or providing cash transfers) or food assistance programmes (such as providing meals, food vouchers or food parcels to food insecure households) (Table 4.1). Food assistance programmes often focus on infants, children, students, and vulnerable and elderly people; the idea is that these target groups are otherwise less able to access sufficient food. Giner and Placzek (2022) discuss in more detail how different approaches are used in OECD countries.

Table 4.1. Policy responses to food insecurity

Programmes	Aim	Instruments	Impacts on food insecurity
Livelihood support programmes	To provide livelihood support	Cash transfers	Indirect via poverty reduction
Food assistance programmes	To provide food to vulnerable population groups	Provision of meals	Direct
		Provision of food vouchers	Direct
		Provision of food parcels	Direct

Source: Giner and Placzek (2022).

4.2. Food systems are expected to deliver on a “triple challenge”

Food systems are expected to deliver several essential services, which can be summarised as the “triple challenge” of providing food security and nutrition for a growing population, providing livelihoods to those working along food supply chains, and ensuring environmental sustainability (OECD, 2021).

These multiple objectives matter for discussions of the resilience of food systems for at least two reasons. First, in discussing policy options to strengthen resilience, it is important to avoid optimising for a single objective (e.g. resilience in terms of food security), as this will rarely be sufficient to achieve the other objectives, and may even undermine them (e.g. when environmentally unsustainable practices are encouraged). A holistic approach to food systems resilience should not only account for these trade-offs, but should also seek to maximise synergies. For example, by following principles of responsible business conduct (RBC), firms may prioritise actions that would also help strengthen their resilience. This could occur through several channels (OECD, 2021e). Before a disruption occurs, RBC may help by reducing the probability and severity of foreseeable shocks on which businesses have some influence (e.g. more

responsible use of water resources could help reduce the risk and severity of water stress; firms with better health and safety practices are likely better equipped to protect their employees and hence minimise disruptions to economic activity). If firms embed RBC in their processes, it may also increase their ability to identify and prepare for shocks (e.g. through an increased understanding of the structure of their supply chains, and through more robust risk management frameworks). After a shock has occurred, RBC may also help by reducing the risk that shocks will negatively impact worker livelihoods and the environment. Empirical evidence from the COVID-19 crisis indeed suggests that firms with better RBC practices also performed better economically (OECD, 2021e).

Second, the search for food systems resilience takes place in a context where food systems are at present far from achieving the triple challenge (OECD, 2021) – so any concept of resilience that focuses merely on the ability of a system to *maintain* its function or return to it rapidly after a shock is not sufficient. Indeed, OECD (2020b) identified three key capacities for resilience: the ability to absorb, adapt, and transform. Hence, to achieve resilience, food systems must go beyond merely absorbing and adapting. There is widespread consensus in the scientific community that food systems will need some degree of transformation to simultaneously achieve the "triple challenge" while improving resilience (Caron et al., 2018; Fan, 2021; Fanzo et al., 2021; Ruben et al., 2021; Singh et al., 2021; von Braun et al., 2023; Webb et al., 2020). This need for an urgent transformation of food systems was also recognised in the *Declaration on Transformative Solutions for Sustainable Agriculture and Food Systems* from the 2022 meeting of OECD Agriculture Ministers.

4.3. Food systems are themselves an important source of pressures

While food systems are subject to a wide range of pressures, food systems themselves also create pressures which can affect their own long-term resilience and that of other sectors and systems. Food production (in particular land use, land use change, and primary production) is a major source of environmental pressures, including in terms of water use, biodiversity loss, eutrophication, acidification, and greenhouse gas emissions (Poore and Nemecek, 2018). These pressures in turn degrade essential ecosystem services (IPBES, 2019).

Food systems may also be a source of threats to animal and plant health. For example, extensive use of antimicrobials in livestock production may lead to antimicrobial resistance (AMR), which can form a threat to animal health (and potentially human health) in the long run (Morel, 2019; Anderson et al., 2020; Ryan, 2021). Plant pests and diseases may also spread when appropriate sanitary measures are not in place.

While food is indispensable for human health, food systems may also have negative effects on human health. As noted earlier, foodborne diseases were estimated to cause 420 000 premature deaths globally in 2010, mostly in low- and middle-income countries in Asia and Sub-Saharan Africa (Jaffee et al., 2019). Animal agriculture and the expansion of farming into wildlife habitats may also facilitate the emergence of zoonotic diseases (infectious diseases which are transmitted from animals to humans) (Jones et al., 2013); and one concern with antimicrobial use in livestock production is that this may indirectly contribute to human antimicrobial resistance. Furthermore, unhealthy diets are a major cause of morbidity and mortality worldwide (Afshin et al., 2019) and also contribute to overweight and obesity, which impose important costs in terms of human health, as well as economic productivity (OECD, 2019b). Obesity, in turn, is a major risk factor for greater severity of COVID-19 (Alberca et al., 2021). Unhealthy diets can reduce resilience to infectious diseases. Put differently, efforts to create more sustainable food systems and to encourage healthier diets could help increase resilience in other areas as well.[13]

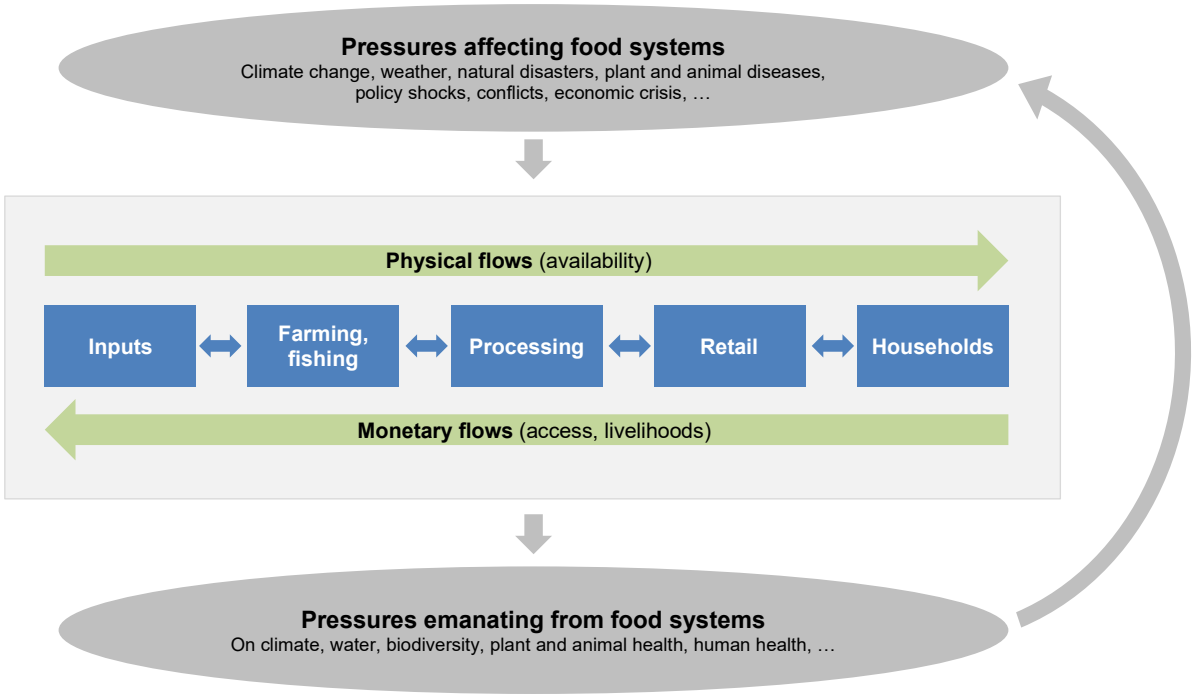
As this discussion makes clear, many of the pressures emanating from food systems in turn affect food systems themselves, such as when excessive water withdrawals create greater vulnerability to drought in the long run, or when plant and animal disease outbreaks emerge from agricultural production and, in turn, affect that production. Similarly, agriculture both contributes and is vulnerable to risks related to water scarcity and pollution, as well as climate change.

[13] For a general discussion on policies to create more sustainable food systems, see OECD (2021b). On policies to encourage healthier diets, see Giner and Brooks (2019); on initiatives to improve the environmental sustainability of food supply chains, see Deconinck and Hobeika (2022).

4.4. Towards a more holistic view of food systems resilience

Figure 4.1 provides a simplified diagram to illustrate some key aspects of a more holistic view of food systems resilience. At the centre of the diagram is a stylised representation of the food supply chain, starting with inputs (e.g. fertilisers, energy, as well as natural resources such as water or soil health); farming, fishing, and other primary production activities; processing; retail; and finally, the consumption of food by households. The arrows connecting these stages represent other economic activities, e.g. trading and logistics. These connections often cross international borders: as noted above, some 20% of global calories consumed have crossed at least one international border, and roughly one-third of this agri-food trade crosses at least two borders.

Figure 4.1. A holistic perspective on food systems resilience



Source: OECD analysis.

As indicated in the diagram, the food supply chain involves physical flows, moving towards the final consumer, as well as monetary flows, moving in the other direction. The term “supply chains” is often used to emphasise the physical flows, while the term “value chains” highlights the monetary flows. These monetary flows matter because food systems provide livelihoods for millions of people; and it is a useful reminder that household income is an important driver of food security.

The top of the diagram represents the wide range of shocks which can affect food systems. These include weather conditions (such as droughts, floods, or heat waves), plant and animal pests and diseases (such as Fall Armyworm and African Swine Fever), policy shocks (such as sudden export bans), conflicts (such as civil wars, or the Russian war of aggressions against Ukraine), and economic crises (which can affect the purchasing power of households). This list is not exhaustive, as many other factors could affect food systems (e.g. cybersecurity risks, volatility in currency markets, etc). Several of these shocks (e.g. extreme weather events, but also certain pests and diseases) are also becoming more frequent or more severe due to climate change (IPCC, 2022).

Shocks can affect various aspects of the food supply chain. For example, animal diseases may directly impact farm production, but where these pose a potential threat to human health they may also lead to sharp reductions in demand, and potential trade restrictions imposed by importing countries.

The bottom of the diagram highlights that food systems themselves are often a source of pressures reducing resilience elsewhere – and that many of these pressures in turn affect food systems themselves.

Another important feedback loop, not shown on the diagram, concerns household incomes derived from livelihoods in food systems. Especially in lower- and middle-income countries, food systems account for a sizeable share of economic activity and employment. As countries develop, the relative role of agriculture typically falls, but other activities along the food supply chain often gain in importance (e.g. wholesale, processing, food preparation, retail) (World Bank, 2007; Barrett et al., 2020; Yi et al., 2021). As a result, shocks to food supply chains may affect food security not only through disruptions in physical flows, but also through negative income effects (IPCC, 2022). This particular feedback loop is usually less of a concern in high-income countries, although the COVID-19 pandemic is an important exception, as livelihoods in many parts of the food supply chain were affected (e.g. through closures of restaurants).

4.5. Managing resilience blind spots

Many of the possible connections in Figure 4.1 have not been studied in detail, reflecting a broader problem of evidence gaps on food systems, especially regarding interaction effects and feedback loops (Deconinck et al., 2021). Traditionally, much research has focused on farm-level risks to production and income (OECD, 2009; OECD, 2014b), on the role of international trade and food supply chains, and on determinants of food security. Recent events show the importance of better understanding other aspects of resilience in food systems, however, such as the role of the processing stage or the possible disruptive effects of major demand shifts as witnessed during the early months of 2020.

The unexpected shocks associated with COVID-19 illustrate the importance of blind spots in food systems resilience. Some factors affecting food systems in the future are reasonably well-known, such as population growth. Other factors are less well-known, but there exist important gradations of uncertainty. Some future events may not be known exactly (e.g. future weather patterns), but it is possible to imagine different outcomes and even to estimate probability distributions. Some other future events are harder to assess (e.g. the risk of a future pandemic), but it is possible to imagine their outcomes, and it may also be possible to assign rough probability estimates (e.g. based on historical records combined with expert consultations). In both of these cases, the uncertain events are “known unknowns”: they may not be known with precision, but the decision maker is aware of their possibility and can therefore take them into account in the decision-making process. For example, the World Economic Forum’s annual Global Risks Report provides an overview of major economic, social, geopolitical, technological, and environmental risks as perceived by a global network of experts (World Economic Forum, 2023).

But decision makers also face “unknown unknowns”: events which may affect outcomes, but which are completely unknown to the decision maker and hence not taken into account. These can give rise to “black swans”: unexpected events with a major impact (Taleb, 2007).

In some cases, these events may have been unknowable. For example, several political revolutions were wholly unanticipated, even by participants themselves (Kuran, 1989); and some (although not all) scientific discoveries or technological breakthroughs may come as a surprise, even to experts.

But in other cases, decision makers may simply have failed to properly inform themselves. Events described as “black swans” often turn out to have been knowable in principle. For example, the financial crisis of 2007-9 had a significant impact precisely because many decision makers had not taken into account the possibility of a collapse of the US housing market and its ramifications – but several traders had spotted signs of weaknesses and had adjusted their strategies accordingly (Lewis, 2010). Similarly, while the emergence and impact of COVID-19 was unanticipated by many decision makers, major pandemics have recurred throughout history and had been highlighted as possible risks by several observers long before the outbreak of COVID-19 (Drake, 2021).

The three types of unknowns require different approaches.

- For *known unknowns*, decision makers can invest in reviewing historical evidence, asking input from experts and stakeholders, and statistical modelling to get a better understanding of the impact and likelihood of different possible events.
- To avoid being vulnerable to *unknown unknowns* which are in principle knowable, decision makers should invest in knowledge and insights from a wide range of sources, including scenario analysis, foresighting exercises, and seeking input from experts and stakeholders.
- To manage *unknowable* unknowns, decision makers should invest in building adaptability, as well as continuous monitoring for unexpected events.

Hence, two important general strategies for food systems resilience are *participatory* approaches involving a wide range of stakeholders, and *building adaptability* (OECD, 2020b). These approaches are useful even when dealing with more familiar risks, but they are particularly useful in reducing vulnerability to blind spots.

A practical challenge with implementing these approaches is that a range of cognitive biases may cause decision makers to focus on known unknowns – in turn increasing their vulnerability to unknown unknowns. For example, people often prefer to remain ignorant when they have the possibility of learning negative information. People may also prefer to avoid learning about their own ignorance, and avoid learning new information after they have made a decision (Gigerenzer and Garcia-Retamero, 2017). Other cognitive biases include the availability heuristic (where the probability of an event is judged based on how easily a concrete example comes to mind) and confirmation bias (where people seek out information confirming their existing views). It is however possible to identify best practices and design processes to reduce the potential for bias (Tetlock and Gardner, 2016). For example, in a “pre-mortem” exercise, participants are asked to imagine that a proposed project has failed, and then work backwards to discuss the possible ways in which this can happen (Klein, 2007). This exercise prompts people to think about risks, and can reduce the problems of overconfidence and groupthink.

5. Conclusion

Well-functioning food systems are essential for human well-being, and the question of the resilience of food systems is rightly high on the policy agenda. But food systems are complex, consisting of all the elements and activities related to producing and consuming food and their effects, including economic, health, and environmental outcomes. If these broader aspects are ignored, policy makers may fail to identify impactful policy instruments, may end up strengthening resilience in one area while harming other food systems objectives, or may even undermine long-term resilience of the entire system. Because of this complexity, coherent policies to strengthen resilience should be based on a holistic view – taking into account the full set of food systems objectives (including not only food security and nutrition, but also livelihoods and environmental sustainability), the full range of possible shocks (including those not currently known – i.e. “blind spots”), and a correct understanding of the functioning of food systems.

This paper made three contributions to a more informed debate on food systems resilience. First, the paper reviewed trends in the organisation of food supply chains (international trade and global value chains, market structure and concentration, and just-in-time supply chain management). Second, the paper reviewed the historical performance of food supply chains (in terms of food availability and affordability) in response to shocks. Third, this paper has argued for the importance of placing the analysis of food supply chain resilience within a broader food systems perspective.

Food supply chains have historically proven to be resilient to a wide range of shocks; temporary, but sometimes large, price increases appear to be the most common impact. Government responses to food supply chain shocks can be beneficial (e.g. providing support to low-income households; helping to alleviate bottlenecks), but the frequently used tool of export restrictions exacerbates price increases and instability.

While analyses of food supply chains provide important insights, the resilience of a single food supply chain is not sufficient to understand food supply in the aggregate, for example because consumers can often

substitute other products. Understanding food security also requires a broader lens: other factors (notably poverty and conflict) are often a more important source of food security risks than food supply chain shocks.

A broader view on the resilience of food systems must also consider other major food systems objectives, including livelihoods and environmental sustainability, as well as the pressures generated by food systems themselves. These pressures can affect food systems themselves (e.g. environmental degradation which reduces long-term productivity) as well as other domains (e.g. unhealthy diets which affect public health). These longer term 'chronic' stresses must be taken into account, in addition to the 'acute' short term disruptions (e.g. due to natural hazards) which are often the focus of policy discussions. Finally, building food systems resilience also depends on addressing "blind spots", possible risks which are not currently on the radar.

An important open question is which frameworks and governance approaches are best suited to achieve this holistic approach to food systems resilience. Major elements can however already be identified, at the farm level and for supply chains in general.

Earlier OECD work has developed a framework for agricultural risk management which distinguishes between normal business risks (which are the responsibility of producers and other private firms), larger risks that can be handled with market solutions (such as insurance systems and futures markets), and catastrophic risks that require stronger government engagement (OECD, 2011). This framework was augmented by OECD (2020b) to include additional processes for fostering preparedness and recommendations regarding the responsibilities of stakeholders. With respect to processes, recommendations include: i) a stronger focus on *ex ante* policies and prevention, and considering longer time horizons to bring into consideration a greater range of potential risks; ii) a clearer consideration of trade-offs (e.g. whereby actions to improve resilience in the short term, or in one part of the sector, can undermine resilience in the longer term, or in another part of the sector); and iii) a stronger focus on a collaborative approach. The additional recommendations regarding the responsibilities of stakeholders include a greater focus on developing stakeholders' own resilience capacity (e.g. through investments in human capital) and "no-regrets" public investments that can increase resilience as well as productivity and sustainability (e.g. early warning systems, peer-to-peer learning).

OECD work on resilient supply chains emphasises the importance of anticipating risks, minimising exposure, building trust, and keeping markets open.[14] There are important responsibilities here for governments (e.g. in developing risk management strategies for essential supply chains, in investing in better infrastructure, and in working closely with private stakeholders and other governments), but public efforts are best directed at the most severe types of risks which cannot be borne by the private sector. The work also highlights that many actions can improve both productivity and resilience, and that governments should refrain from "beggar thy neighbour" policies such as export restrictions.

These frameworks contain many of the elements needed for a holistic approach to food systems resilience. Still, some questions remain, such as the governance arrangements needed to capture broader aspects of food systems. Earlier work by OECD (2021b) emphasised that better policy *processes* are key to achieve better policy *outcomes* in food systems, especially when trade-offs and synergies across different policy domains exist. From this point of view, there are some unresolved questions. For example, should governments develop an integrated strategy specifically for food systems resilience? What are best practices for doing so? Does this require novel governance arrangements (e.g. public-private partnerships)? What could be the role of private-sector supply chain organisations (e.g. industry associations, sectoral business roundtables) in strengthening resilience? Further work on these questions could usefully be undertaken.

[14] See OECD (2020), Keys to Resilient Supply Chains, https://www.oecd.org/trade/resilient-supply-chains/

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