Futures 149 (2023) 103140

Contents lists available at ScienceDirect

Futures

journal homepage: www.elsevier.com/locate/futures

Future foods: Morphological scenarios to explore changes in the UK food system with implications for food safety across the food chain

Kenisha Garnett [*], Joao Delgado [1], Fiona A. Lickorish, Simon J.T. Pollard, Angel Medina-Vaya, Naresh Magan, Paul Leinster, Leon A. Terry

Cranfield University, School of Water, Energy and Environment, College Road, Cranfield, Bedfordshire MK43 0AL, UK

ARTICLE INFO

Keywords:
Scenario building
Food system
Brexit
Pandemic
Consumer safety

ABSTRACT

Scenarios are used to examine systemic change in food systems so policy makers can craft opportunities to improve the management of uncertainty and shape food policy. We present a number of alternative scenarios of the food system for 2035, developed with the Food Standards Agency, the independent government department working to protect public health and consumers' interest in relation to food for England, Wales and Northern Ireland. To build scenarios we employed morphological analysis; a non-quantified method for modelling multiple scenario variables (food system drivers, projections), simulating their interactions and all possible scenario combinations. A cross-consistency analysis compared all possible scenario combinations to identify which set of driver projections formed a logical (internally consistent) scenario. Recently, we augmented the scenarios to consider the potential impacts and consequences of Brexit and the pandemic on consumer food safety. Outputs illustrate the consequences of extreme impacts emerging from an optimistic (Global Trading) and pessimistic (Resource Tensions) future for the food system. The scenarios establish a context for foresight in decision-making and a framework for evaluating the robustness of policies considering the opportunities and challenges arising from Brexit and a global pandemic.

1. Introduction

1.1. Background

Scenarios are a set of plausible, sequentially linked perspectives on the world that could occur in the future (Jarke et al., 1998). They are used to create knowledge about future developments, to consider potential risks and opportunities, and so improve our understanding of the consequences of current and proposed actions (Durance & Godet, 2010; Parson, 2008; Swart et al., 2004). Scenarios have been used to examine the potential implications for food systems from shock events (e.g. cyber-attacks), population growth, climate change, increasing urbanisation, fuel price fluctuations, changes in consumption patterns and other resources (Hamilton et al., 2020; O'Keefe et al., 2016; Lakner & Baker, 2014; Vervoort et al., 2014; Chaudhury et al., 2013; Godfray et al., 2010;

* Corresponding author.
E-mail address: k.garnett@cranfield.ac.uk (K. Garnett).
[1] University of Exeter Medical School, RILD Building, Barrack Road, Exeter, EX2 5DW, UK

https://doi.org/10.1016/j.futures.2023.103140
Received 8 June 2021; Received in revised form 15 November 2022; Accepted 16 March 2023
Available online 20 March 2023

Hubert et al., 2010; Ambler-Edwards et al., 2009).

Brexit – the UK leaving the European Union (EU) – has created significant uncertainties for trade within the EU and supply chain risks associated with the UK's dependency on food from Europe. However, forging new trade relationships, post-Brexit, offers opportunities to reconfigure the food system to deliver better health and environmental outcomes, while ensuring the system remains resilient, sustainable and profitable (Benton et al., 2019; Petetin, 2020).

The rapid spread of the Covid-19 pandemic has had significant impact on the world triggered by national lockdown and social distancing measures intended to control the disease. These policy measures have caused major disruption to the food system including price volatility, periodic food shortages and reductions in food quality and security, loss of income and livelihoods, and a widening of inequality (Davies et al., 2021; Clapp & Moseley, 2020; Laborde et al., 2020). While the effects of the pandemic are still emerging, there may be future threats to food safety, security and nutrition depending on the severity and timescale of impacts caused by the disease and policy measures to contain it (CFS, 2020). An OECD (2020) report on the impact of the pandemic suggests that the rapid response and resilience of food supply chains in western countries confirm the need for an open international trading environment, which will allow companies to access new sources of supply when existing ones are compromised. The UK food strategy (2022) suggests that while international food security is dependent on a combination of open markets and dispersed food production, national resilience is reliant on successful domestic production in an uncertain world (Defra, 2022).

Global challenges such as the pandemic has renewed interest in the concept of a "sustainable food system", where competing and conflicting objectives related to food security, nutrition, health, income, environmental sustainability, and culture (Béné et al., 2019) require equitable trade-offs to secure social, environmental, and economic outcomes from the food system (FAO, 2018). Vågsholm et al. (2020) argue that food safety is fundamental to securing a sustainable food system and requires careful balancing with other complementary elements (e.g., food security) amidst multiple challenges arising from extraneous factors (e.g., Brexit, the pandemic), which can disrupt and significantly alter food environments and generate uncertainties around social, economic and environmental outcomes. Alternative future scenarios support building a better understanding of uncertainties about the consequences of disruption and, in turn, helps reveal innovative and resilient policies for a sustainable future. The process highlights dependencies and conditions that help describe how a set of events might play out, and provides a more holistic assessment of the consequences of interventions before planning.

This paper summarises research conducted with the Food Standards Agency (FSA; England, Wales and Northern Ireland) in which three alternative states of the UK food system were envisaged for 2035, guided by the research question "*what are the plausible future states of the UK food system in 2035, and what risks and opportunities do these futures pose for different actors in the food chain*"? The research was carried out between 2012 and 2014 and involved multiple organisations and stakeholders to develop scenarios that explored plausible developments for the UK food system and examined the strategic risks and opportunities these futures posed. The scenarios were re-assessed to consider the implications of recent significant events - Brexit and the pandemic – and the implications for consumer food safety. Case studies for two food types (i.e., a processed product, raw food/ingredient and feed/ingredient) were developed to: (1) explore triggers for change in the UKs' food production and supply, and (2) asses the impacts and consequences of change (particular those sharp disruptions), and the implications for food safety under each scenario.

1.2. Scenario development to study food systems

Policy-makers use scenarios to test policy choices, making them more adaptive to external changes in the long-term (O'Keefe et al., 2016; Moreira et al., 2015; Volkery & Ribeiro, 2009). Understanding the disruptions and shocks that could impact the food system, and their likely causes (Bailey et al., 2015) requires a systemic approach that considers the future states of the system and the interactions between different pressures or drivers of change. How these drivers interact and the resulting consequences that emerge for the food system and its beneficiaries is highly uncertain and so scenario analysis can play a key role.

Studying the complex, multi-dimensional context of food systems (Ericksen et al., 2009) requires a participatory approach to ensure parties with a legitimate interest are engaged in framing and addressing the challenges (Vervoort et al., 2014; Ingram et al., 2013; Godfray et al., 2010; Reilly & Willenbockel, 2010). Such challenges are usually explored at a macro level where emphasis is on systemic issues, such as a malfunctioning food system and include social, economic, political, environmental, biophysical and institutional dimensions (Reilly & Willenbockel, 2010). The process of building scenarios involves deliberative techniques such as participatory workshops, Delphi exercises and computer-based modelling to structure and analyse the problem space.

Scenarios are "exploratory" and they blend existing trends with uncertainties about future developments by analysing how drivers of change (current or likely to emerge) evolve and interact (Kok et al., 2011; Pillkahn, 2008; Parson, 2008; Bradfield et al., 2005; Böjeson et al., 2005). Reilly and Willenbockel (2010) suggest that exploratory scenarios describe drivers of change that are outwith the control of the actors for whom the scenarios are being developed; for example, resource use and climate change as exogenous factors with variable impacts on food systems. However, scenarios should also include internal drivers, such as agreed food safety strategies and policies, to address the deficiencies in system failures and policy lock-ins. Exploratory scenarios use intuitive methods of development that carry out an assessment of validity based on the *scenario logic*; i.e., whether the scenarios present a "plausible" view of the future, capture 'relevant' issues that adequately explain system complexities, and sufficiently 'challenges' current thinking (Chermack, 2011). Scenarios evolve with time so they must be updated to reflect new events and possible consequences (Henriques et al., 2015; Haasnoot & Middelkoop, 2012). For example, our food system scenarios have been updated in light of recent political events such as Brexit and socio-economic disruption caused by the pandemic to explore potential consequences for the food system and its beneficiaries.

2. Methodology

2.1. Scope of the study

Scenarios were developed in close collaboration with the UK Food Standards Agency (FSA), and took a long-term perspective in assessing changes within the UK food system (i.e., towards 2035) and the potential risks to, and opportunities for, ensuring consumer food safety across the food chain. The geographic scope of the study was national and international to facilitate taking a macro-level perspective of food system developments, and to assess the implications for different food chain actors. Consumer food safety and food hygiene was a particular focus, given the remit of the Food Standards Agency to enforce food safety regulations.

2.2. Scenario approach

To build the scenarios we employed morphological analysis (Ritchey, 2011); a non-quantified method for modelling multiple scenario variables (drivers, projections), simulating their interactions and displaying all possible scenario combinations. The process consisted of four steps: (1) scoping the key drivers of change influencing food system developments, (2) defining the key driver projections, (3) building the scenario logic and, (4) creating the scenario narrative. In light of Brexit and the effects of a global pandemic, we updated each scenario narrative to incorporate new information and uncertainties about food system developments to ensure they are up-to-date, and remain plausible.

2.2.1. Key drivers of change

Our assessment of drivers used current knowledge and assumptions about the future, gathered through a workshop involving a range of experts, to explore: *"what are the main drivers of change influencing food system developments"*. Thirty-two experts from government, academia and the food industry represented the broadest range of expertise including food science (e.g., food microbiology, food safety), food preparation and retail, social science, economics and risk management. The workshop took the format of a brainstorming exercise, using PESTLE analysis (Brown, 2007) to consider a wide range of interdependent drivers of change across the entire food system: Political, Economic, Social, Technological, Legal and Environmental categories.

Experts were split into three groups. Researchers (KG, JD, AM and FL) facilitated group discussions and encouraged participants to identify a broad range of drivers, including those relatively familiar or certain (i.e. current and largely within their control) and those unfamiliar or uncertain (i.e., long-term and largely outside of their control). Issues raised in group discussions, framed by the different PESTLE categories, were recorded and later collated for study as a whole. Researchers clustered similar issues to avoid duplication, and assigned a nominal title for each driver (e.g., "international trade") that later required a normative judgement on how the issue was driving and shaping food systems in 2035 (e.g., international trade agreements would lead to a more stable increase in commodity prices). Experts reviewed the clusters and refined the labels, before prioritising drivers. A total of 13 key drivers were prioritised by experts as important to shaping the future of the UK food system (Table 1).

Table 1
Key drivers description.

Pestle	Key driver	Brief description
Political	International trade and relations	UK's political position/influence in Europe and abroad, and its trading policies and relations with other countries.
Economic	Global markets	Operation of international markets expressed as the movement (flow) of goods and resources (imports / exports) globally.
	State of the UK economy	The size and future growth of UK's economic output, measured by real GDP and average growth per year.
	Cost of living / disposable income	Disparities in spending power in relation to the affordability of food, based on household disposable income.
Social	Population size	Number of individuals living in the UK and possible changes, reflective of birth and death rates, and level of immigration.
	Families and household	Type of households and family composition (e.g., couple, single parent or lone person).
	Consumer attitudes and behaviour	Consumption levels related to lifestyle choice, attitude to food, health and level of social/community engagement.
Technological	Innovation and adoption of technology	Technological development (including new technology) for the production, preparation and distribution of food.
	Information communication technology	Role and impact of information communication technologies (ICT) in providing information on, and access to, food and engaging communities in food debates.
Legal	European Union legislation	Role of European Union to define laws, directives and agreements that drive food policies and identify responsibilities for food safety.
	Nature of regulatory environment	Effect of attitudes and approaches to risk, and approaches taken to develop and implement food policies and controls.
Environmental	Climate Change	The UK's capacity to assess vulnerability, and to mitigate and/or adapt to climate change and its consequences.
	Price and availability of resources	Changes in the price and availability of resources (ingredients and food products) from production through to distribution of food.

2.2.2. Key driver projections

Next, the projections – relevant states or conditions that each key driver could assume in the future – were explored by researchers, relying on expert opinion gathered at a second workshop to define the projections of plausible change in each driver (Fig. 1). The second workshop involved 31 experts from organisations similar to those that attended the first workshop.

Experts were placed in groups to explore: *"what alternative plausible state could each driver assume in 2035"*? This required defining a range of values that covered all possible states of the drivers in 2035. Delineating the extremities of change in a particular driver was challenging for experts as they had to consider all possible states of that driver in 2035, while ensuring that each state (or projection) was sufficiently independent (Stenström, 2013; Chermack, 2011). To overcome this, researchers worked with experts to define the end points of the value range that illustrate the most extreme 'conceivable' (plausible) forms of change. Researcher prompted experts to think about 'extreme' change by asking them to consider departures from the status quo. For example, experts were asked to consider (1) what could significantly shift consumer values and choices, (2) what role might retail brands play in shaping consumer values and choices, and (3) how could major socioeconomic change impact on consumption?

"Food price" and "retail brands" were defined as the key determinants of consumption choices and used to illustrate the extremities of change (i.e., price-led consumption as one extreme and retail-led consumption at the other extreme). Having defined the end points of the value range, the discussion moved to defining the interval points between extreme values; i.e., two mid-points (unsustainable consumption, informed and responsible consumption). The driver projections were refined through an analysis of the literature and validated through interviews with independent experts, agreed with the FSA, to ensure a consistent and plausible set of projections were established for each key driver.

2.2.3. Scenario logic

This step involved carrying out a cross consistency assessment (Ritchey, 2011) to compare all possible scenario combinations in order to identify which set of driver projections could be combined to form a logical (internally consistent) scenario (Fig. 2).

The cross-consistency analysis was carried out by researchers comparing all possible combinations of driver states or projections in order to identify those consistent projections that could logically co-exist in a scenario. This involved carrying out a binary assessment of each possible combination of projections to make a judgement on the possibility of a driver state (i.e. possible event) occurring, following the occurrence of another driver state (Voros, 2009). In other words, researcher made a judgement about the influence of projection X^1 of driver X on projection Y^1 of driver Y, based on information extracted from the literature and through expert interviews, expressed using the following qualitative scale:

- + 3 high consistency / likely to occur in the same scenario.
- + 2 moderate consistency / likely to occur in the same scenario.
- + 1 low consistency / likely to occur in the same scenario.
- 0 no consistency nor likelihood to occur in the same scenario.
- -1 low inconsistency / unlikely to occur in the same scenario.
- -2 moderate inconsistency / unlikely to occur in the same scenario.
- -3 high inconsistency / unlikely to occur in the same scenario.

International trade & relations	Global markets	State of the UK economy	Cost of living/ disposable income	Population size	Families & household	Consumer attitudes & behaviours	Innovation & adoption of technology	Information & communi-cations technology	EU legislation	Nature of the regulatory environment	Climate change	Price & availability of resources
Influence of emerging economies comparable to western levels	Increased globalisation of markets	Steady Growth	Increasing food prices alongside disposal income	Stabilisation of population size	No real change to families and households	Price-led consumption	Limited investment and adoption of new technology	Free information is used by industry but not the public	Compromise model	High levels of regulation	Mild to modest effects from climate change	Volatility of markets limits access and increases prices
Global trade agreement	Stable globalisation of markets	Strong Growth	Decreasing food prices alongside disposal income	Increase driven by global population trends	Progressive but stable change to families and households	Unsustain-able consumption	Sourcing technology from foreign suppliers	Free information is used by industry and public	EU legislation with a world market focus	Medium levels of regulation	Gradual increase in effects from climate change	Market agreements lead to stable access and prices
Trade wars	Decreased globalisation of markets	Modest Growth	Increase in food prices but a decrease in disposable income	Increase driven by immigration	Radical change to families and households	Informed and responsible consumption	The UK at the forefront of research and development activities	Industry uses information and tailors industry/consu mer interactions	A greater EU	Low levels of regulation	Proactive reduction of climate change	Government intervention regulates access and prices
Regional alliances		Predominant periods of recession	Increase in disposable income with a real decrease in food prices			Retail-led consumption		Technology has less significant role due to a lack of information	World market without EU		Adaptation to volatile climate change	

Fig. 1. Morphological matrix showing key driver projections (based on Author *et. al.*, 2014).

		Global markets			State of UK economy			
	Judgement section: consistency of driver projections	Increased globalization of markets	Stable globalization of markets	Decreased globalization of markets	Steady growth	Strong growth	Modest Growth	Predominant periods of recession
International trade and relations	Influence of emerging economies comparable to western levels	2	1	0	0	-2	1	0
	Global trade agreements	3	3	1	2	2	0	-1
	Trade wars	-3	-3	1	-2	-2	2	3
	Regional alliances	0	2	1	0	0	1	1
Global markets	Increased globalization of markets				2	2	0	-3
	Stable globalization of markets				1	1	0	-1
	Decreased globalization of markets				0	-3	1	3

Fig. 2. Cross consistency matrix (partial representation of the matrix, presented in full in Appendix 1).

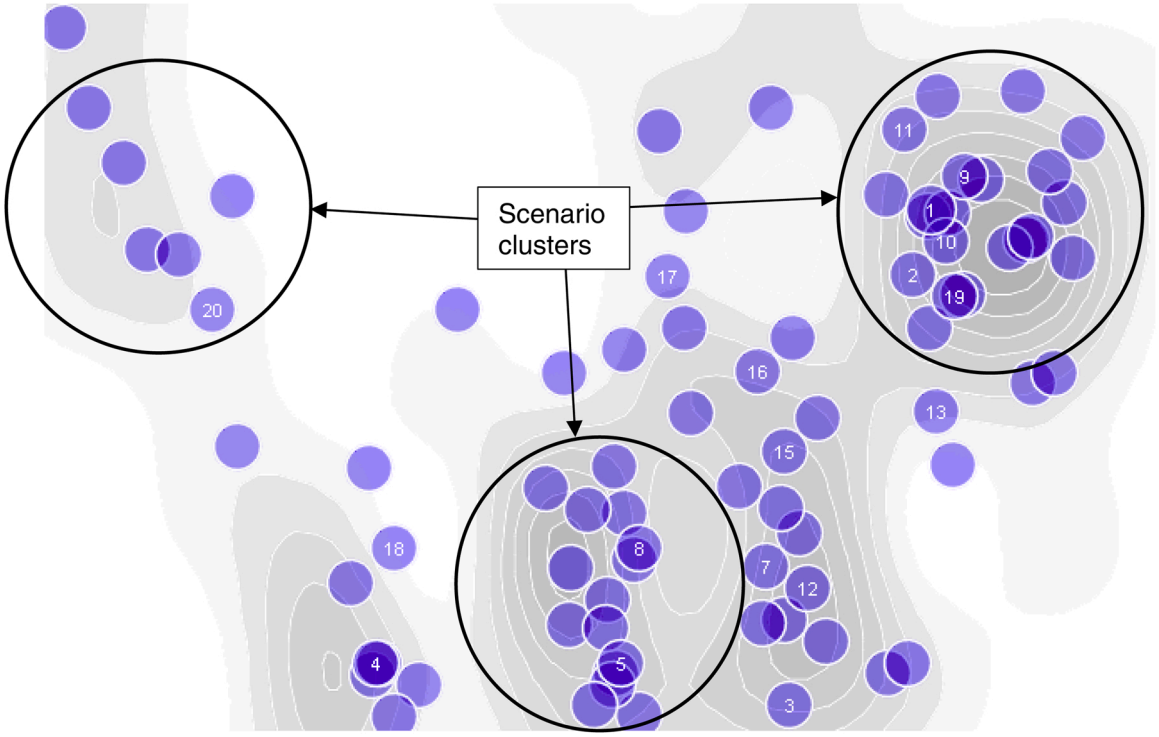

Fig. 3. Scenarios clustered in groups of similar combination of projections (distance between clusters = scenarios with distinctly different combination of projections). Final scenarios selected from the clusters circled.

The matrix (Fig. 2) establishes a network of 11,943,936 possible scenario combinations (determined by the multiplying all the projections under each driver). Next, researchers performed a cross consistency assessment, using a morphological scenario simulation software tool (Paramenides EIDOS; https://www.parmenides-eidos.com/eidos9/us/). The scenario simulation tool uses an algorithm to compute the systemic balance of influences in the matrix. It processes and excludes inconsistent combinations of projections, thereby reducing the total set of all possible scenario configurations to a smaller set of highly consistent configurations. The top 25 scenarios with the highest consistency scores were selected for further analysis with a final set of three draft scenarios selected, reflecting a highly plausible and relevant combination of drivers, each a different and challenging view of the future (Fig. 3).

2.2.4. Scenario narratives

Scenario skeletons were next constructed for *each scenario state* that described how the future might unfold through fixed events, supplemented by 'explicit story-lines' of a progression from the present to the future. For example, *"food poverty and huge resource scarcity are linked to a prolonged period of economic recession, and a breakdown in European cooperation on trade. These challenging times prompt the UK to broaden its trade policy to include countries in Asia and Latin America in an attempt to stem trade deficits as scarce resources lead to supply chain disruptions and price volatility"*. The logical connection of projections for each scenario was checked, as well as the consistency of the story-line in order to validate the scenarios. Validation was carried out in consultation with experts from the FSA as to whether the scenarios presented a logical, plausible and challenging set of assumptions about the future and included the most relevant issues/drivers discussed in the workshops. This resulted in the modification of some scenario projections and story-lines to refine the scenario frame, and extend current thinking in a way that made the scenarios both challenging and plausible.

In revising the scenarios, we retained the core drivers and projections from earlier research, but the scenario narratives were revisited and subsequently updated by food science academics to explore the potential impacts and consequences of recent events (e.g. Brexit, the pandemic) on consumer food safety. The narratives were revised to consider the possible consequences of these events on the food system, reflecting on the combination of drivers in each scenario to interpret the future state of the food system and the possible impacts and consequences of recent events on different actors in the food system. For example, in the Global trading scenario, new trade arrangements are established in the UK, largely under the World Trade Organisation (WTO) rules, which is expected to improve market access to goods and services from other countries, thus increasing productivity, employment and wages that could lead to higher investment in the food sector.

An illustration of the structure of a scenario is provided in Fig. 4, and the description and analysis of the "two extremes" scenarios are presented in Sections 3.2 and 3.3.

2.2.5. Case studies

The food safety implications of the scenarios were assessed for a range of actors. While the focus was on consumer food safety, other issues related to food sustainability and security – availability, accessibility, and affordability of food – were considered. Food safety implications for two food types are included to show how the scenarios could be adopted to assess the potential impacts and consequences of Brexit and the pandemic for specific produce and for relevant actors in the food system. Researchers supported the translation of information from discussion among academics and food industry experts to generate insights used to draw out implications. Outputs are expected to shape discussion in policy teams about the level of preparedness, rather than serve as prescriptive

International trade & relations	Global markets	State of the UK economy	Cost of living/ disposable income	Population size	Families & household	Consumer attitudes & behaviours	Innovation & adoption of technology	Information & communi-cations technology	EU legislation	Nature of the regulatory environment	Climate change	Price & availability of resources
Influence of emerging economies comparable to western levels	Increased globalisation of markets	Steady Growth	Increasing food prices alongside disposal income	Stabilisation of population size	No real change to families and households	Price-led consumption	Limited investment and adoption of new technology	Free information is used by industry but not the public	Compromise model	High levels of regulation	Mild to modest effects from climate change	Volatility of markets limits access and increases prices
Global trade agreement	Stable globalisation of markets	Strong Growth	Decreasing food prices alongside disposal income	Increase driven by global population trends	Progressive but stable change to families and households	Unsustain-able consumption	Sourcing technology from foreign suppliers	Free information is used by industry and public	EU legislation with a world market focus	Medium levels of regulation	Gradual increase in effects from climate change	Market agreements lead to stable access and prices
Trade wars	Decreased globalisation of markets	Modest Growth	Increase in food prices but a decrease in disposable income	Increase driven by immigration	Radical change to families and households	Informed and responsible consumption	The UK at the forefront of research and development activities	Industry uses information and tailors industry/consu mer interactions	A greater EU	Low levels of regulation	Proactive reduction of climate change	Government intervention regulates access and prices
Regional alliances		Predominant periods of recession	Increase in disposable income with a real decrease in food prices			Retail-led consumption		Technology has less significant role due to a lack of information	World market without EU		Adaptation to volatile climate change	

Fig. 4. Set of consistent key driver projections that defines a scenario (morphological box). One of the scenarios created (i.e., Global Trading) is highlighted.

outcomes. An analysis of scenario implications is presented in Section 3.4.

3. Results and discussion

3.1. Extreme impact scenarios

The scenarios developed in this study illustrate the consequences of extreme impacts emerging from an optimistic (Global Trading) and pessimistic (Resource Tensions) future for the food system (Fig. 5). A Reference scenario assumes a future with 'no surprises' and reflects the food system as it exists today. The extreme scenarios set out possible shocks and uncertainties that might challenge the resilience of the UK food system moving forward.

Each of the extreme scenarios have been revisited to consider the current socioeconomic and political climate in the UK, and are discussed below (italicised sub-sections) with respect to possible developments in the food system and the implications for different actors. The original scenarios are available in (Garnett et al., 2014).

3.2. Global trading scenario

After leaving the EU, the UK joins the European Free Trade Association (EFTA) and is able to negotiate a favourable customs arrangement with the EU, resulting in no barriers in trade between UK and EU businesses. Under the rules of the World Trade Organisation (WTO), the UK establishes trade agreements with third countries (e.g. United States, China, Brazil and Australia) by replicating the EU's requirements for imports. While this is challenging to implement initially, strict standards and controls are put in place to ensure the safety and quality of food. Food standards, animal welfare and data protection are prioritised by involving the public and NGOs in the negotiation of the UK's trade policy. WTO rules help maintain an equitable trading platform and increases collaboration between western and emerging economies to improve confidence in international trade.

Trade regulations ensure EU food safety and quality standards are maintained as well as access to high quality products and services. Trade agreements increase the confidence of businesses, following a period of uncertainty during negotiations. New trade agreements increase trade flows, by lowering tariffs and prices for some consumer goods that improve market access to goods and services from other countries. This increases productivity, employment and wages, leading to improvements in global financial conditions and a rise in investments in the food sector.

Overcoming the financial crisis (an unpresented downturn in the economy in 2020 due to the pandemic), the UK recovers well and achieves annual growth rates of about 3 %. A strong export base significantly improves the UK's trade balance. Commodity prices stabilise in a thriving UK economy, providing welfare gains for consumers, including an increase in the variety and access to better quality food, resulting from lower inflation that increases disposable income. Lower trade barriers and imports on goods, particularly in Europe, stimulate investments in advanced food processing and modern technology, which drives innovation across the food sector and create positive changes in food production and consumption patterns.

Reeling from the effects of the pandemic, food supply chains gradually adjust to the sudden surge in demand for food that simultaneously caused surpluses for producers and shortages for consumers. Supermarket shelves are replenished as consumers reduce the volume of food purchased. Homebound consumers demand better access and choice of food and a more personalised food experience, which expands food delivery services and drive innovation to increase delivery efficiencies (e.g., through online delivery platforms, virtual brands and other delivery infrastructure and services). A relaxation of immigration rules assures a flow of seasonal

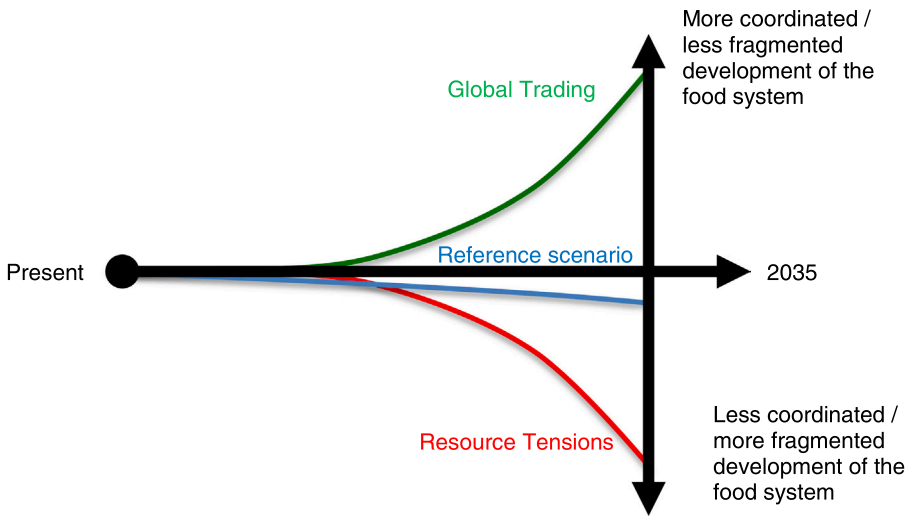

Fig. 5. Scenario plots (based on Kohler, 2021; Voros, 2003).

workers from Europe, while a larger number of Government apprenticeship programmes are developed for the agri-food industry, and these increase the skills of the domestic workforce, alongside pay and productivity, to reduce economic imbalances between social groups across the food sector. Figs. 6 and 7.

3.2.1. Consumers

The expansion of trade and advancement of technology in the food sector provides consumers with seemingly "limitless choice". High costs of energy, land, fertiliser and water raise food prices, but this is compensated by increases in salary and disposable income. The latter is associated with better access to affordable food, which also reduces levels of food poverty to pre-recession levels. Consumer interest in the environment, health and social well-being significantly increase after the pandemic and this is reflected in responsible, and often healthier, diets mainly among those of high socioeconomic standing in society. Greater demand for plant-based protein products, meat and dairy alternatives is linked to a climate-friendly agenda and greater awareness of the health benefits of food, fuelled by pandemic-related concerns.

Smart technologies in the home provide consumers with an unprecedented amount of information about the safety and nutritional value of foods, reducing food waste. Advanced technologies (e.g., cheap home sensors) enable automated ordering online, customisation and personalisation of flavours. Greater awareness of the links between diet and good health mean consumers demand innovation and greater responsibility of businesses, although not all consumers based their choices on healthy, ethical or sustainable considerations. The demand for specialist produce in niche markets (e.g., ethnic and organic foods) increases with a more informed and nuanced population that has a greater proportion of immigrants.

Although higher levels of disposable income improve the accessibility and affordability of food for most consumers, income disparities and the rising costs of food limit choice for poorer consumers. This increased food security risks for consumers who were most affected by food poverty as a result of the pandemic (e.g., vulnerable groups such as the elderly, chronically ill and poorer households). Recognising poorer consumers, who tend to spend proportionally more on food, are most affected by high food prices, the UK Government works with the food industry to implement new technology and information about the impacts of food on human health and the environment to safeguard vulnerable consumers.

3.2.2. Food and non-food retailers

Major economies (e.g. UK, EU and US) as well as new global leaders from emerging economies (e.g., South East Asia, India and South America) lead the global food market. A net increase in the global flows of goods and resources is associated with the growth in the UK food imports and exports, where imports are sourced from a diverse range of countries. Access to information across the whole food chain (e.g., stock levels, production techniques and conditions, technological developments and patents) is used to optimise production, trade and manage the food chain (demand forecasting and source management). The UK maintains high levels of innovation in new food technology and achieves more digitised supply chains, which enable retailers to personalise products and achieve greater diversification, specialisation and differentiation of their brand. Coupled with a changing structure of households, suppliers tailor their goods and services to meet changing demands and demographic needs. Multiple retailers expand stocks of functional food and drinks to meet consumer demand for products that support greater immunity and good health (e.g., gut-friendly drinks and fermented foods).

The growth in online shopping (and automated ordering) prompts a rise in the number of shared distributions system, such as

International trade & relations	Global markets	State of the UK economy	Cost of living/ disposable income	Population size	Families & household	Consumer attitudes & behaviours	Innovation & adoption of technology	Information & communi-cations technology	EU legislation	Nature of the regulatory environment	Climate change	Price & availability of resources
Influence of emerging economies comparable to western levels	Increased globalisation of markets	Steady Growth	Increasing food prices alongside disposal income	Stabilisation of population size	No real change to families and households	Price-led consumption	Limited investment and adoption of new technology	Free information is used by industry but not the public	Compromise model	High levels of regulation	Mild to modest effects from climate change	Volatility of markets limits access and increases prices
Global trade agreement	Stable globalisation of markets	Strong Growth	Decreasing food prices alongside disposal income	Increase driven by global population trends	Progressive but stable change to families and households	Unsustain-able consumption	Sourcing technology from foreign suppliers	Free information is used by industry and public	EU legislation with a world market focus	Medium levels of regulation	Gradual increase in effects from climate change	Market agreements lead to stable access and prices
Trade wars	Decreased globalisation of markets	Modest Growth	Increase in food prices but a decrease in disposable income	Increase driven by immigration	Radical change to families and households	Informed and responsible consumption	The UK at the forefront of research and development activities	Industry uses information and tailors industry/consu mer interactions	A greater EU	Low levels of regulation	Proactive reduction of climate change	Government intervention regulates access and prices
Regional alliances		Predominant periods of recession	Increase in disposable income with a real decrease in food prices			Retail-led consumption		Technology has less significant role due to a lack of information	World market without EU		Adaptation to volatile climate change	

Fig. 6. Global Trading. Morphological box showing a mix of projections.

International trade & relations	Global markets	State of the UK economy	Cost of living/ disposable income	Population size	Families & household	Consumer attitudes & behaviours	Innovation & adoption of technology	Information & communi-cations technology	EU legislation	Nature of the regulatory environment	Climate change	Price & availability of resources
Influence of emerging economies comparable to western levels	Increased globalisation of markets	Steady Growth	Increasing food prices alongside disposal income	Stabilisation of population size	No real change to families and households	Price-led consumption	Limited investment and adoption of new technology	Free information is used by industry but not the public	Compromise model	High levels of regulation	Mild to modest effects from climate change	Volatility of markets limits access and increases prices
Global trade agreement	Stable globalisation of markets	Strong Growth	Decreasing food prices alongside disposal income	Increase driven by global population trends	Progressive but stable change to families and households	Unsustain-able consumption	Sourcing technology from foreign suppliers	Free information is used by industry and public	EU legislation with a world market focus	Medium levels of regulation	Gradual increase in effects from climate change	Market agreements lead to stable access and prices
Trade wars	Decreased globalisation of markets	Modest Growth	Increase in food prices but a decrease in disposable income	Increase driven by immigration	Radical change to families and households	Informed and responsible consumption	The UK at the forefront of research and development activities	Industry uses information and tailors industry/consu mer interactions	A greater EU	Low levels of regulation	Proactive reduction of climate change	Government intervention regulates access and prices
Regional alliances		Predominant periods of recession	Increase in disposable income with a real decrease in food prices			Retail-led consumption		Technology has less significant role due to a lack of information	World market without EU		Adaptation to volatile climate change	

Fig. 7. Resource tensions. morphological box showing the mix of projections.

Amazon, that compete with traditional supermarket retail chains. A high increase of consumers preparing meals at home (accelerated by the pandemic, greater consciousness about health risks) prompt food retailers and restaurants to adopt end to end customisation to ensure consumer preferences (e.g., vegan, gluten free options, food allergies) are accounted for in store orders and restaurant menus, and increase the accuracy of recommendations on apps that are now tailored to individual preferences. This enables consumers to source customised, personalised foods from a larger number of retailers, and directly from manufacturers and producers, which reduces the power of retailers.

3.2.3. Catering

UK Government 'sustainable food' policy is targeting food safety problems and nutritional issues within food businesses (e.g., restaurants, pubs, bistros, cafes). Consumers are engaged and more informed about the health and safety of food. Higher levels of disposable income mean that people can afford to be more altruistic in their choice (e.g., making more ethical and sustainable choices). Food businesses adopt hi-tech operations to provide a "gastronomic" experience for a growing number of people that eat out regularly at restaurants, bistros, pubs and canteens, but demand higher quality, more nutritious and tasty foods. The diversity of consumers and their varied demands mean there are more heterogenous restaurants that provide specialist and personalised foods, for example, organic, fusion and ethnic foods.

Lockdown and physical distancing measures during the early stages of the pandemic gave a huge boost to new online delivery methods (e.g., click and collect services), user friend apps and tech-enabled systems (mobile delivery robots) with delivery service becoming a significant feature in the 'dining landscape'. A proliferation of "dark kitchens" (i.e., restaurants with no front of house for customers) and other delivery-first and delivery-only restaurants emerge after the pandemic, putting pressure on traditional restaurants, some of which opt out of providing delivery services altogether (adopting the "tiny restaurant" model) while others cease the opportunity to supplement on-premise facilities with exclusive delivery services located in remote areas. Virtual concierge services improve delivery efficiency allowing the "stacking up" of individual or community orders from restaurants, supermarkets and non-food services (e.g., dry cleaning) in a single trip.

3.2.4. Processing, production and supply

Multilateral trade agreements reduce export subsidies and improve market access to agriculture, industrial and primary products, reverting some export restrictions put in place early in the pandemic. WTO members release a joint declaration of their commitment to open international trade during the pandemic. This benefits the UK in terms of reduction in trade-distorting domestic product and improves equity in international trade, but also increases exposure to new risks from animal diseases, contamination, adulteration and mislabelling of food products.

As economic conditions improve globally, the UK Government invests in research and development that drives innovation in the production, distribution and monitoring of goods, and improves technical skills within the food sector. The relaxation of some certification procedures and regulations on the trade of food (e.g., food labelling requirements) are reversed following the pandemic. A relaxation of immigration policies and safeguarding strategies are adopted to assure the continuity of domestic food production and the health and safety of food workers (e.g., factory, seasonal workers). These measures protect the functioning of food supply chains and build resilience to future disruption and shocks. Automated tracking systems are used to assess product compliance to environmental and social requirements and improve traceability in food supply chains. Combined, these efforts help maintain the UK's lead

position in food manufacturing and reforms the food system with new models of food production and consumption, particularly in the alternative protein, seafood and horticulture sectors.

New technologies are adopted on farms to produce food, including bioengineered and modified crops and artificial meat that is considered a super-nutritious and environmentally friendly food product. Consumers demand for safe, healthy and sustainable foods prompt investment in food technologies and innovation in processing, production and supply, which enhance the quality of ingredients and improve diets through better distribution and preservation of, and access to, food. Recognising the market value of convenient, superior quality food, some producers develop counterfeit products that mimic high-end goods, which are often sold through online food platforms and food traders, where traceability has reduced amidst a proliferation of online food trading platforms.

3.3. Resource tensions scenario

After leaving the EU, the UK secures a Trade and Cooperation Agreement with the EU, but this breaks down due to a lack of reciprocal arrangements that allow for rapid action against subsidies granted for commodities (e.g., food materials and raw ingredients), posing a risk to industries and livelihoods. After numerous failed arbitration procedures, the UK exits the UK-EU Trade and Cooperation Agreement, resulting in a "backstop" arrangement for Northern Ireland, where EU customs rules still applies. Under the WTO rules, the UK enters new customs arrangements with the EU, some of which mirror the Comprehensive Economic and Trade Agreement (CETA) between the EU and Canada. While CETA reduces trade barriers between the UK and EU countries, tariffs increase for some agricultural products (e.g., pork and poultry).

Strict border checks ensure UK businesses are certified as compliant with EU standards and measures, but these gradually reduce trade flows between the UK and the EU due to delays and inefficiencies at borders. Faced with high prices for its imports and exports to the EU, the UK broadens its trade policy to include preferential agreements with other countries (e.g., USA, Australia, New Zealand, Asia and Latin America). Export restrictions imposed by some third countries in response to the pandemic remain, creating volatility in European and global markets and reduce food imports to the UK. This increases domestic production, but food prices also rise particularly for the commodities still imported.

Reeling from the effects on the pandemic, there are growing challenges due to resource shortages in a declining global economy, which creates a climate of distrust between trading parties, leading to an increase in WTO disputes. The lack of trust, power struggles and geopolitical instability causes countries to prioritise their own interest, which affects the level of openness in international markets and leads to trade wars. UK trade suffers from shortages of foods, historically imported from the EU, resulting in price volatility and supply chain disruptions. The cost for major fertilisers (some of which are energy intensive to produce) is at an all-time high due to rising oil prices resulting from geopolitical tensions in Europe and latent effects of disruption to supply chains caused by the pandemic. Similarly, logistics and transport have slowed down and are more expensive with higher fuel costs due to the energy crisis coupled with disruption and delays at ports.

Declining economic activities in the UK food sector, coupled with a long-term downturn in the economy due to the financial crisis in 2020, creates unemployment and reduces investment opportunities, resulting in a decrease in the availability of safe and nutritious food. The effect of the pandemic is still felt with a visible disconnect between supply and demand for certain foods (e.g. meat, diary), which is related to insufficient domestic food production and labour challenges in the UK food system.

3.3.1. Consumers

A declining economy has transformed consumers' attitude to food. There is a growing consciousness about the price of food and greater interest in foods that help people stay satiated. Some consumers opt for basic rations, reducing food portions and increasing the stockpiling of dried, frozen, canned or other long-lasting foods. Stockpiling lowers the level of surplus food in retail businesses, as it did in early phases of the pandemic, which reduces the amount of food redistributed to food banks and charities to support those in need. Poor access to food has improved consumers' self-sufficiency, where those who can afford to choose to grow and trade food through peer-to-peer platforms to supplement food purchases. Home grown produce is often at high cost, which makes alternative foods such as those grown in laboratories more desirable due to their lower comparative costs.

The decrease in disposable income in a declining economy is linked to a persistent rise in food poverty, which sees some consumers choosing to ration food as a means to safeguard against future disrupted supplies. Effects of the pandemic have exposed inequalities in the way food is produced and distributed, increasing food security risks among vulnerable groups (e.g., elderly, chronically ill, poor households) with very little financial support and access to food (e.g., lack of resources that compromises food redistribution). There is little variety in consumer diets as access to sufficient food for survival is prioritised, particularly for those consumers on lower incomes who have lost interest in the provenance of food and make choices based on price. The focus on "value for money" results in people making unsustainable (and often unhealthy) food choices and as a consequence some struggle with diet-related diseases. Overall, consumers appear more tolerant of risks in the current economic climate, prompting a change in food safety standards (e.g., higher mycotoxin levels, removal of food restrictions such as the ban on chlorinated chicken) and a more liberal attitude to new food technologies (e.g., nanotechnology).

3.3.2. Food and non-food retailers

Pressure to maintain food supply in the UK has encouraged some incidents of food adulteration and mislabelling in the food chain (e.g. deliberate mislabelling of GM products as non-GM, failure to disclosure additives in some food products), facilitated by the relaxation of food labelling requirements that remained after the pandemic. Delivering a consistent and reliable supply of safe food is challenging in the current economic climate. Some retailers responded by integrating their supply chains to gain greater flexibility and

better access to food supplies, while others chose to source products from a wider range of intermediaries. Bottlenecks in transport arising from border control delays cause food shortages and reduce stock availability in retail outlets. Retailers take drastic measures to get goods to retail stores and consumers, reducing varieties to boost quantities and accepting high-demand items that are of poor quality.

Retailing has undergone a transformation in the UK with an increase in food fraud, substitution and adulteration driven by the need of retailers to maintain marginal profits. "Black markets" emerge for high-cost goods that are difficult to source, but these are often of dubious origin and quality where safety standards are compromised. Along with traditional supermarkets, there is a growth in smaller opportunistic traders (e.g., mobile food trucks) where goods in high demand are sourced (e.g., dried, canned or other long-lasting foods). These food trucks are also used to supply food directly to households, distribute food in areas of food poverty and to support informal trading and swapping of good through peer-to-peer online platforms. Online shopping and local deliveries are used to boost sales but it also improves access to a wider variety of foods, often at a premium price.

3.3.3. Catering

Eating out is reserved as a treat for special occasions. The small portion of people eating out order food free (e.g., through available charities) or at a reduced cost directly from food traders. Other enterprises (e.g., public sector and social enterprises) are working to reduce food poverty and have increased the range of food catering operators in the sector and consequently their market share. There is a small number of takeaways, coffee shops and restaurants that survive the pandemic and remain open, but largely cater to more affluent consumers and those who tend to eat out on the odd occasion. Like retailers, there is pressure for restaurants, bars and other catering establishments to reduce costs and maintain marginal profits, while meeting the demand for cheap food. The economic crisis has significantly increased the turnover of staff and the reduction in training has resulted in a lack of skills needed to implement good quality control and food safety measures. The lack of resources and trained staff often results in a compromise on the quality and safety of food (e.g., tampering with use-by dates and substitution of raw ingredients).

3.3.4. Processing, production and supply

Failure to reverse the slump in international trade has led to huge trade deficits in the UK as scarce resources are frequently interrupted. Bilateral trade agreements with non-EU countries allow UK businesses to access cheaper imports, although some of these have lower quality and sustainability standards compared to the EU. Increasingly, it becomes difficult for UK businesses to compete with products imported from non-EU countries that are produced more cheaply and at lower standards. A spin-off is the relatively low responsiveness to consumer demand that creates greater diversity in quantity and quality of products.

Food poverty is linked to higher levels of risk tolerance across the population. This has created accountability and traceability issues in the food chain, which has led to food safety problems related to microbial contamination (e.g. mycotoxins) and food fraud. Since more consumers are sourcing food directly from producers and suppliers, there is an economic advantage in substituting ingredients with lower quality materials, but this increases the health risk to consumers. There is a drive toward intensive farming to maximise production yields, but the shortage of farm workers (heightened by immigration controls imposed post Brexit and mobility restriction early in the pandemic) causes disruptions in some sectors such as livestock production, horticulture, planting, harvesting and crop production. Changing attitudes has led to the promotion of GM crops and foods across the UK with little objection from the public. Farming techniques have altered as some farmers adopt novel biotechnologies that enable harvesting of, for example, perennial crops that can re-grow each season without having to reseed. These new farming practices see a change in the selection of crops grown and consumed locally.

3.4. Implications of the scenarios for consumer food safety

Each scenario has different implications for food production and supply in 2035. Two important foods in UK diets are used as case studies to explore what food safety implications might emerge under each scenario:

- ***Meat*** which is a primary food product and key ingredient, and constitutes one of the main sources of protein in a typical diet for most people in the UK.
- ***Soya*** which is an important source of food ingredients providing plant protein, fibre, essential fatty acids, vitamins and minerals in human diets and also as an animal feed component.

Below we consider the implications of each scenario and examine the potential risks and opportunities posed for each raw ingredient and the subsequent processing of the commodity into food or feed. Each case reflects on what food safety issues might emerge, and provides insights into, for example, what interventions may safeguard against risks to the food (or feed) chain, and support consideration of what regulatory responses might be needed (e.g., safety standards or controls). The main implications are summarised in Sections 3.4.1 to 3.4.2.

3.4.1. Meat

Despite stable levels of meat consumption in the UK, quantities of meat imported from non-EU countries (e.g. Argentina and Brazil) have significantly increased over the last decade or so (FAO, 2012). Meat exports to non-EU countries have also increased, but variable prices for premium cuts have revealed larger gains in exporting lower-value cuts and offal products to countries such as China and West Africa where these products have higher value (AHDB, 2019). Some countries in the Latin America region are of high risk for food

safety issues due to a myriad of socio-economic challenges and the impacts of climate change (DARA, 2012; Medina et al., 2017), which raises issues for the UK around food safety. Additional concerns related to countries with known cases of food fraud (e.g., substituted horse meat, adulterated produce; i.e., Sudan I in chillies) also raise food safety issues. Hence, it is becoming increasingly important to identify vulnerabilities and potential risks in the meat food chain to ensure food safety standards and controls remain effective in protecting consumers and ensuring food safety (Table 2).

3.4.2. Soya

Soya products have become a main part of UK diets and is consumed primarily as a replacement of meat, processed meats such as burgers and sausages, tofu and dairy alternatives (e.g., yogurt and milk). Plant protein of both fermented and unfermented soya is similar to animal protein, which makes it a key component for animal feed and food ingredients. A report by the New Economic Foundation (2017) suggested that the use of protein crops in livestock feed has reduced due to increasing reliance on imported commodities such as soya beans. Brexit could lead to changes in the UK subsidies regime that may transform the incentives for farmers to grow soya and other protein crops. Local cultivation of soya beans could provide import substitution buffers against rising food prices, although increases in production could have implications for tariffs and trade to the extent that it reduces trade flows between

Table 2
Scenario implications for the meat supply chain.

Scenario	Global trading	Resource tensions
Key features	*EU standards for the safety and quality of foods are maintained through strict standards and quality controls. In a strong economic climate, investment and technological advances in food manufacturing and processing drive innovation in the food system, including personalisation and customisation of products to meet diverse demographic needs and changing preferences for sustainable, healthy foods, fuelled by the effects of the pandemic.*	*New customs arrangements with EU and non-EU countries introduce food safety and quality issues. Tough economic conditions increase consumers' tolerance of risk and sees a rise in opportunistic trading that increases food fraud. This is enabled through regulatory change including a reduction in safety controls such as labelling requirements, which is retained as a measure to increase international trade during the pandemic. Poor access to food improves the self-sufficiency of some consumers through grow-your-own and peer-to-peer trading, but those on household incomes source alternative, cheaper foods that may have consequences for their diets and health.*
Consumers	A larger number of consumers source foods based on the sustainability and ethics of brands, amidst growing awareness of the impact livestock production on the environment. This leads to an increasing trend of locally sourced meat that drives good standards and quality of meat in the UK with some consumers choosing more environmentally friendly meats like chicken.	Decrease in domestic meat production resulted in higher prices for meat and meat products that is unaffordable for many consumers with some opting for cheap, low quality options that contribute to food insecurity. Others seek meat substitutes and alternative sources of protein, some of which have dubious origins and pose a risk to consumer health and nutrition. There is an increase in the consumption of processed foods containing lower quality meat ingredients at fast food outlets.
Food retailers and caterers	Increasing capabilities to trace ingredients has improved product information and consumers' trust in the wider range of meat products in retail outlets. The prevention and reduction of product packaging waste is high on the agenda, demanding improvements that extend the shelf life of meat products (e.g., plastic-free and bio-packaging, novel active packaging systems), but these increase the risk of microbial contamination through the migration of chemical substances or toxins into meat products.	Financial constraints have increase food safety risks, where meat shelf-life is compromised due to traceability issues. Some supermarkets opt to limit high-demand items such as beef and pork and food outlets reduce the amount of meat products sold (e.g., meat pies, beef burgers). Retailing is poorly monitored resulting in an increase in the number of small, illegal retailers trading without proper hygiene practices, capitalising on rising demands for low-cost meat and meat products. This leads to an increase in incidents of meat-related food poisoning and infections.
Processors	Meat production plants have become increasingly mechanised with technological improvements that increase the range of end products available to meet struct hygiene and quality requirements and diverse demographic needs. Automation in processing plants replaces the need for manual packaging and labelling of meat products and reduces human errors that increase food safety risks, and lower resilience to disruption (e.g., mobility restrictions on workers). Issues around bacterial pathogens arise due to an increase in the number of processing plants in operation, where some prove challenging to regulate and control hygiene and food safety standards.	Meat is purchased from producers selling at the cheapest price, which increases quantities imported from non-EU countries sold at lower prices. Domestic meat production and processing is compromised due to scarcity of animal feed, transportation of live animals due to seasonal border crossing restrictions. Production is also affected by the lack of hygiene standards and poorly trained staff, which increase the risk of microbial and chemical residue contamination. This risk is significant for highly processed meat products that are exposed to contaminants that accumulate at each step in the supply chain (e.g., meat substituted with undeclared or illegal cuts, tainted meat). Poor disposal practice also create biosecurity risks and unfavourable effects on the environment.
Producers and suppliers	New technologies (e.g., robotics) are put in place to increase productivity, enhance quality control and improve the safety of meat production, which allows for maintaining higher quality standards and enhance product integrity. There is good sourcing of ingredients and quality of feed to support meat production, reducing latent concerns around the quality, freshness and safety foods prominent during early stages of the pandemic. This ensures high microbiological safety and nutritional quality, which enable low to minimum contamination of meat due to the presence of bacterial pathogens and associated disease issues from animals or food chains.	Local meat producers adopt intensive farming systems to compete with cheaper meat products sourced from abroad, which impacts on the quality of meat produced. Resource pressures caused by the pandemic decrease governmental capacities for surveillance and ability to prevent, control and treat animal disease, which means that producers put less effort into controlling pathogens during production. Some producers use of harsh chemical or treatments to reduce levels of pathogens in meat, but this reduces the quality of meat produced (e.g., chlorinated or irradiated chicken). The presence of growth hormones and antibiotics in imported food can increase resistance to microorganisms, which makes it difficult to control diseases from bacterial pathogens.

the UK and EU. Nonetheless, the large amount of GM and non-GM soya beans consumed in the UK, which is imported from the United States and Latin America (e.g., Brazil and Argentina), may affect the contingencies required for soya derivatives and ingredients and how it is processed into food or feed (Table 3).

4. Conclusions

In both Global Trading and Resource Tensions scenarios, significant food safety risks and disruptive events can emerge as a consequence of socio-economic challenges and technological innovation in food systems.

- **Global trading:** an innovation-driven food sector has changed production and consumption patterns, where consumer interests in environmental and social issues lead to more responsible (and sometimes healthier) diets, largely among those of higher socio-economic status.
- **Resources tensions:** a declining food economy challenged by increasing food prices mean consumer choice is limited, reflecting preferences for cheaper foods, high in facts, salt and sugar leading to diet-related diseases and greater tolerance of food safety risks.

In Global Trading, greater awareness of the need for more resilient supply chains including of critical inputs (e.g., fertilisers) has emerged since the pandemic. A number of adaptive measures have been integrated into the food system to improve food security and the agility of supply chains in response to future shocks. Some of these include (1) securing adequate access to labour to support the continuity of domestic food production, (2) bridging the skills gap in the agri-food industry to enhance pay and reduce economic imbalances across the sector, (3) adopting innovations in logistics, distribution and storage to improve flexibility in order to better cope with rapid or sudden change to retail demand, and (4) increasing climate resilience and reducing greenhouse gas emissions through productivity improvements, sustainable farming and land-use change.

Advances in modern technology and food processing stimulate innovation in the food system and create new models for food production and consumption. These models are already emerging as seen with multicomponent foods and cultured or alternative proteins (see FAO, 2013). However, the high cost of these foods, cooking skills and longer time taken to prepare healthy meals compared to convenience foods, which are often high in fat, sugar and salt, are not accessible to those on low incomes. Alternative foods also bring added complexity to supply chains and manufacturing processes and require more segregation and control. For example, new and alternative proteins may cause major implications for food safety, where issues related to allergens and the nutritional quality of ingredients would require harmonisation and equivalence of standards and regulatory frameworks that pushes the boundaries of current food safety guidance.

A growing trend in consumers concerned about the provenance, quality and safety of food has led to greater product differentiation with more variety in product quality. Higher levels of disposable income aids and encourages consumers to demand more choice and higher standards of quality, origin and welfare. This extends the global range of products and the need to trade on international markets to source ingredients through traceable and safe supply chains. Whilst empowering consumers, globally sourced foods have the potential to circumvent established mechanisms of providing consumer protection, where high food prices can lead to poor diet choices that increase health inequalities, especially of people on lower incomes. Food safety controls and regulations would need to be adapted to take into account advances in technologies, including personalised foods/diets, online/automated ordering, and shared distribution systems.

In the Resource Tensions, economic challenges and resource scarcity means there is relatively low responsiveness to consumer demand, where for example, retailers who struggle to maintain profit margins produce large quantities of goods which are low in quality and nutrition. Trade restrictions in the European and international markets are retained after the pandemic to safeguard food security in a declining economic climate. Market volatility significantly increase food prices (e.g., meat, fruit and vegetables, beverages) encouraging more domestic production to address food security challenges, but rising food shortages in deprived areas create opportunities for illegal trading of scare products (e.g., pork, vegetables). Consumers, faced with increasing food prices, make poor food choices resulting in increased consumption of, for example, fast foods and processed meats that contain lower quality ingredients. A growing number of illegal retailers capitalise on an increasing low-income consumer market and trade without appropriate hygiene controls (i.e., selling meats of dubious origin), which has significant implications for food safety and the health of consumers. In this scenario, an increase in microbial diseases (e.g., bacterial pathogens) and exposure to bacterial toxins and mycotoxins would occur, which puts further pressure on health services. Food safety regulations may be compromised, and it may become more difficult to ensure implementation by the various stakeholders in key food chains. The costs involved in effective surveillance to identify these risks will be increased which may not allow effective implementation. The overall risks associated with “unsafe” foods, will also have knock-on effects on health impacting on diet/nutrition-related diseases such as obesity and heart disease.

The scenarios provoke learning, develop strategic insight and enable a shift in thinking and practice. The participatory process revealed unfamiliar factors of development and raised awareness around uncertainties. The next logical step is moving from the scenarios to action, which requires a structured approach for testing the robustness of food policy options and identify future sector developments and socio-economic conditions that might significantly hinder or enhance the achievement of food safety and food security priorities against possible future scenarios (Henriques et al., 2015), namely:

- Testing current or alternative strategy or policy against the different scenarios and determining how achievable or desirable the strategic priorities are for the future.

Table 3
Future implications for the soya supply chain.

Scenario	Global trading	Resource tensions
Key feature	*EU standards for the safety and quality of foods are maintained through strict standards and quality controls. In a strong economic climate, investment and technological advances in food manufacturing and processing drive innovation in the food system, including personalisation and customisation of products to meet diverse demographic needs and give assurances to an increasing number of consumers who source foods based on the sustainability and ethical ethos of brands and changing preferences for sustainable, healthy foods, fuelled by the effects of the pandemic.*	*New customs arrangements with EU and non-EU countries introduce food safety and quality issues. Tough economic conditions increase consumers' tolerance of risk and sees a rise in opportunistic trading that increases food fraud. This is enabled through regulatory change including safety controls such as labelling requirements, which is retained as a measure to increase international trade during the pandemic. Poor access to food improves the self-sufficiency of some consumers through grow-your-own and peer-to-peer trading, but those on household incomes source alternative, cheaper foods that may have consequences for their diets and health.*
Consumers	Consumers are inherently more conscious about the environment which influences their food choices, where for example, concerns for food miles prompt responsible sourcing of soya. Reduced meat consumption also increases the demand for soymeal related feed. Advancement in product inspection technology, quality assurance schemes and voluntary sustainability standards with environmental and social requirements play a key role in ensuring soya products sourced locally (and small quantities still imported) are labelled correctly, do not contain foreign body contaminants and are safe to eat.	A downturn in the economy has had an impact on lower-income families who suffer from malnutrition and diet-related diseases. There is lower consumption of soya and soy-derived products (e.g., soybean oil) with less people eating out at restaurants, who are major users of vegetable oil. Alternatives such as GM soya derived products are available at low price due to their low protein content and widely consumed as a replacement for high priced meat cuts, resulting in protein deficiencies and related health impacts (e.g., stunted growth).
Food retailers and caterers	There is an increase in soya derive products in the UK, as protein crops are produced more competitively in Europe compared with imported plant proteins. Soya imports from Europe increase causing different grades of soya products to appear on the market, requiring greater controls be put in place to ensure compliance to EU standards. Growing demand for soya products does mean increasing imports from abroad, largely South America (Argentina and Brazil) and USA and Canada, where certification schemes assure (to some extent) the quality of soy imports.	While there is an increase of GM soya derived products for human consumption, there is a parallel reduction in the supply of GM and non-GM soya for animal feed and increase in the use of alternative proteins (e.g., combination of rapeseed, beans and peas). Increasingly, retailers source soya and soya by-products from unregulated suppliers in countries where there have been historic freezes in trade because of food safety scandals. Poor economic conditions make it difficult for retailers to maintain monitoring and quality control programmes leading to increased food safety risks.
Processors	New food manufacturing and processing technologies have improved food quality, but some soya waste products with high levels of contaminants risk entering the food chain as animal feed (e.g., cows fed with contaminated soy meal). To some extent this is alleviated by consumers who demand high quality soya products and are willing to pay the price.	The number of food fraud incidents have increased as soya products are replaced with alternatives (e.g., cheaper raw materials) to cut costs. However, this compromises the integrity of soya products (e.g., soya milk for lactose intolerant consumers) causing allergen problems.
Producers and suppliers	A tradition in UK diets mean soya is in high demand with a large portion of soybean/meal imported from but growing concerns around the environmental impact of soy production abroad impact its retail value. UK farmers are incentivised to adopt more sustainable agriculture practices, where new cultivars (heat, climate resistant crops) have compensated for lower yields in the domestic market. Investment in best in class, real-time monitoring techniques result in less end point, pre-processing checks for contamination. There is growing interest in the use of feed additives to reduce methane emission from livestock, lowering reliance on soyabean for animal feed, but the lack of regulation regarding the use of additives raises concerns about health risks.	There is greater access to pesticides that were restricted under EU regulations, which increases the risks of producing foods contaminated with chemicals. Increase in competition and price for soya means the UK is more receptive to lower quality products. The use of alternative protein sources requires more stringent monitoring and control measures, which puts a strain on limited resources within regulatory authorities. Some UK producers shift to grow GM soya where consumers show willingness to source cheaper GM food. Unregulated GM soya production has high use of agrochemicals and pollution, which contaminates local ecosystems (e.g., water sources), soil and feed livestock.

- Identifying responses that are robust and can address the risks, or exploit opportunities, emerging in each scenario or adopt a strategic position in response to critical areas of uncertainty identified in each scenario.
- Recommending contingencies or controls for treating high-priority risks (or means for exploiting opportunities), where appropriate, to build into the food strategy.

How the food system will develop in 2035 is dependent on technological development and the socio-economic development pathways that dictates vulnerabilities in food supply chains and the adaptive capacity of the different actors, which will vary along the food chain. An analysis of scenario implications, specific to some food groups (e.g., meat and soya), offers insights to interventions that may be needed to mitigate impacts on the food system, and support decision-makers in considering appropriate regulatory responses (e.g., monitoring frameworks, safety controls or standards). Establishing a focus on a particular policy area (e.g., food safety) and associated sectors of interest provided the opportunity to connect external trends with food system priorities. To challenge the status quo, we debated whether the (1) direction of the trends and their projections are a good reflection of current state of knowledge, and (2) potential impacts of trends and vulnerabilities in the food system, and which actors are likely to experience the most change. This exchange between experts made future challenges and opportunities clearer and more compelling for decision-makers. Further research to future-proof food policy or strategy should consider how robust or adaptable options are to address issues that are common to both scenarios as well as those specific to each scenario. It should also consider which policy measures have proven effective and what new strategies may be needed to better respond to disruption across the feed system.

Declaration of interest

None.

Acknowledgment

This research was funded by the Defra Futures Research Partnership (SD0339) and commissioned by the UK Food Standards Agency. SJTP was co-funded by Defra and a cross-Council (EPSRC, NERC, ESRC) grant (EP/G022682/1) awarded to Cranfield University. The authors thank the experts from the Food Standards Agency, numerous government agencies and stakeholders in the food industry for their valuable contribution. The views expressed in this paper are those of the authors only. The scenarios and the implications drawn do not represent UK Government policy nor the policy or position of the UK Food Standards Agency.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.futures.2023.103140. Raw data generated from stakeholder workshops cannot be shared due to ethical and legal reasons.

References

AHDB, (2019). Brexit prospects for UK beef and sheep meat trade. Horizons. Market Intelligence, 2019. https://projectblue.blob.core.windows.net/media/Default/Imported%20Publication%20Docs/BLBitesize_190219_WEB.pdf (Accessed: 15 January 2021).

Ambler-Edwards, S., Bailey, K.S., Kiff, A., et al., (2009). Food Futures: Rethinking UK Strategy. A Chatham House Report. Chatham House (the Royal Institute of International Affairs). Available at: http://orca.cf.ac.uk/20465/1/r0109foodfutures.pdf (Accessed: 10 November 2018).

Bailey, R., Benton, T.G., Challinor, A., et al., (2015). Extreme weather and resilience of the global food system. Final project report from the UK-US Taskforce on Extreme Weather and Global Food System Resilience, The Global Food Security programme, UK.

Béné, C., Oosterveer, P., Lamotte, L., et al. (2019). When food systems meet sustainability – Current narratives and implications for actions. *World Development, 113*, 116–130.

Benton, T., Froggatt, A., Wright, G., Thompson C. and King, R., (2019). Food Politics and policies in Post-Brexit Britain. Energy, Environment and Resources Department & Europe Programme. Chatham House, The Royal Institute of International Affairs. January 2019. https://www.chathamhouse.org/sites/default/files/publications/research/2019–01-10-BentonFroggattWrightThompsonKing.pdf.

Böjeson, L., Mattias, H., Karl-Henrik, D. et al., (2005). Towards a user's guide to scenarios – a report on scenario types and scenario techniques. KTH Architecture and the Built Environment. Stockholm: Royal Institute of Technology.

Bradfield, R., Wright, G., Burt, G., et al. (2005). The origins and evolution of scenario techniques in long range business planning. *Futures, 37*(8), 795–812.

Brown, D. (2007). Horizon scanning and the business environment - The implications for risk management. *BT Technology Journal, 25*(1), 208–214.

CFS, (2020). Impacts f Covid-19 on food security and nutrition: developing effective policy responses to address the hunger and malnutrition pandemic. High Level Panel of Experts (HLPE) on Food Security and Nutrition. Issues Paper. Food and Agriculture Organisation (FAO). Available at: https://www.fao.org/3/cb1000en/cb1000en.pdf (Accessed: 10 October 2022).

Chaudhury, M., Vervoort, J., Kristjanson, P., et al. (2013). Participatory scenarios as a tool to link science and policy on food security under climate change in East Africa. *Regional Environmental Change, 13*(2), 389–398.

Chermack, T. J. (2011). *Scenario planning in organizations – How to create, use and assess scenarios*. California: Berrett-Koehler Publishers,.

Clapp, J., & Moseley, W. G. (2020). This food crisis is different: Covid-19 and the fragility of the neoliberal food security order. *The Journal of Peasant Studies, 47*(7), 1393–1417.

DARA & The Climate Vulnerable Forum., (2012). Climate Vulnerability Monitor: A Guide to the Cold Calculus of a Hot Planet (2nd ed.). Available at: http://daraint.org/wp-content/uploads/2012/09/CVM2ndEd-FrontMatter.pdf (Accessed: 10 November 2018).

Davies, N. G., Jarvis, C. I., Covid-19 Working Group, C. M. M. I. D., et al. (2021). Increased mortality in community-tested cases of SARS-CoV-2 lineage B.1.1.7. *Nature, 593*, 270–274.

Defra, (2022). Government food strategy. Available at: https://www.gov.uk/government/publications/government-food-strategy/government-food-strategy (Accessed: 10 October 2022).

Durance, P. & Godet, M., (2010). Scenario building: Uses and abuses. Technological forecasting and social change, 77(9), 1488–1492.

Ericksen, P. J., Ingram, J. S. I., & Liverman, D. M. (2009). Food security and global environmental change: Emerging challenges. *Environmental Science and Policy, 12*(4), 373–377.

FAO , (2012). FAO statistical yearbook 2012. Available at: http://www.fao.org/economic/ess/ess-publications/ess-yearbook/yearbook2012/en/ (Accessed: 10 November 2018).

FAO, (2013). The contribution of insects to food security, livelihoods and the environment. Available at: http://www.fao.org/3/i3264e/i3264e00.pdf (Accessed: 10 November 2018).

FAO, (2018). Sustainable food systems. Concept and framework. FAO. Available at: https://www.fao.org/3/ca2079en/CA2079EN.pdf (Accessed: 10 October 2022).

Garnett, K., Delgado, J., Lickorish, F., Shaw, H., Rathe, A., Chatterton, J., Prpich, G., and Pollard, S.J.T. , (2014). Plausible Future Scenarios for the UK Food and Feed System – 2015 & 2030. Food Standards Agency (FSA). https://www.food.gov.uk/sites/default/files/media/document/FINAL_FFS_Report-June-2014.pdf (Accessed: 5 September 2018).

Godfray, H. C., Crute, I. R., Haddad, L., et al. (2010). The future of the global food system. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences, 365*(1554), 2769–2777.

Haasnoot, M., & Middelkoop, H. (2012). A history of futures: A review of scenario use in water policy studies in the Netherlands. *Environmental Science & Policy, 19–20*, 108–120.

Hamilton, H., Henry, R., Rounsevell, M., et al. (2020). Exploring global food system shocks, scenarios and outcomes. *Futures, 123*, Article 102601. https://doi.org/10.1016/j.futures.2020.102601

Henriques, C., Garnett, K., Weatherhead, E. K., et al. (2015). The future water environment — Using scenarios to explore the significant water management challenges in England and Wales to 2050. *Science of the Total Environment, 512*, 381–396.

Hubert, B., Rosegrant, M., van Boekel, M. A. J. S., et al. (2010). The future of food: Scenarios for 2050. *Crop Science, 50*, 33–50.

Ingram, J. S. I., Wright, H. L., Foster, L., et al. (2013). Priority research questions for the UK food system. *Food Security, 5*, 617–636.

Jarke, M., Bui, X. T., & Carroll, J. M. (1998). Scenario management: An interdisciplinary approach. *Requirements Engineering, 3*, 155–173.

Kohler, K. , (2021). Risk and resilience Report. Strategic foresight: Knowledge, tools and methods for the future. Federal Commission for Nuclear, Biological and Chemical Protection and the Federal Office for Civil Protection. Available at: https://www.preventionweb.net/publication/strategic-foresight-knowledge-tools-and-methods-future (Accessed: 10 October 2022).
Kok, K., van Vliet, M., Barlund IIona, I., et al. (2011). Combining participative backcasting and exploratory scenario development: Experience from the SCENES project. *Technological Forecasting and Social Change, 78*, 835–851.
Laborde, D., Martin, W., & Vos, R. (2020). Impacts of Covid-19 on global poverty, food security, and diets: Insights from global model scenario analysis. *Agricultural Economic, 52*(3), 375–390.
Lakner, Z., & Baker, G. A. (2014). Struggling with uncertainty: The state of global agri-food sector in 2030. *International Food and Agribusiness Management Review, 17*(4), 141–176.
Medina, A., Akbar, A., Baazeem, A., et al. (2017). Climate change, food security and mycotoxins: Do we know enough? *Fungal Biology Reviews, 31*(3), 143–154.
Moreira, P. V. L., Baraldi, L. G., Moubarac, J., et al. (2015). Comparing different policy scenarios to reduce the consumption of ultra-processed foods in UK: Impact on cardiovascular disease mortality using a modelling approach. *PLOs One, 10*(2).
New Economics Foundation , (2017). Solutions for the farm of the future. Grow Green. The Vegan Society. https://www.vegansociety.com/sites/default/files/Grow%20Green%202%20Full%20Report_0.pdf (Accessed: 10 January 2021).
OECD , (2020). OECD policy responses to coronavirus (Covid-19). Covid-19 and global food systems. Available at: https://www.oecd.org/coronavirus/policy-responses/covid-19-and-global-food-systems-aeb1434b/ (Accessed: 10 October 2022).
O'Keefe, L., McLachlan, C., Gough, C., et al. (2016). Consumer responses to a future UK food system. *British Food Journal, 118*(2), 412–428.
Parson, E. A. (2008). Useful global-change scenarios: Current issues and challenges. *Environmental Research Letters, 3*(4), Article 045016.
Petetin, L. (2020). The COVID-19 Crisis: An opportunity to integrate food democracy into post-pandemic food systems. *European Journal of Risk Regulation*, 1–11. https://doi.org/10.1017/err.2020.40
Pillkahn, U. (2008). Using trends and scenarios as tools for strategy. *Development: Shaping the future of your enterprise*. Wiley-VCH,.
Reilly, M., & Willenbockel, D. (2010). Managing uncertainty: A review of food system scenario analysis and modelling. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365*(1554), 3049–3063.
Ritchey, T. (2011). Modelling alternative futures with general morphological analysis. *World Future Review, 3*, 83–94.
Stenström, M. , (2013). Morphological analysis in groups. A personal guide. FOI-R-3678-SE. FOI, Swedish Defence Research Agency. ISSN 1650–1942.
Swart, R. J., Raskin, P., & Robinson, J. (2004). The problem of the future: Sustainability science and scenario analysis. *Global Environmental Change, 14*(2), 137–146.
Vågsholm, I., Arzoomand, N. S., & Boqvist, S. (2020). Food security, safety, and sustainability – Getting the trade-offs right. *Frontiers in Sustainable Food Systems, 4*, 16. https://doi.org/10.3389/fsufs.2020.00016
Vervoort, J. M., Thornton, P. K., Kristjanson, P., et al. (2014). Challenges to scenario-guided adaptive action on food security under climate change. *Global Environmental Change, 28*, 383–394.
Volkery, A., & Ribeiro, T. (2009). Scenario planning in public policy: Understanding use, impacts and the role of institutional context factors. *Technological Forecasting and Social Change, 76*(9), 1198–1207.
Voros, J. (2003). A generic foresight process framework. *Foresight, 5*(3), 10–21.
Voros, J. (2009). Morphological prospection: Profiling the shapes of things to come. *Foresight, 11*(6), 4–20.