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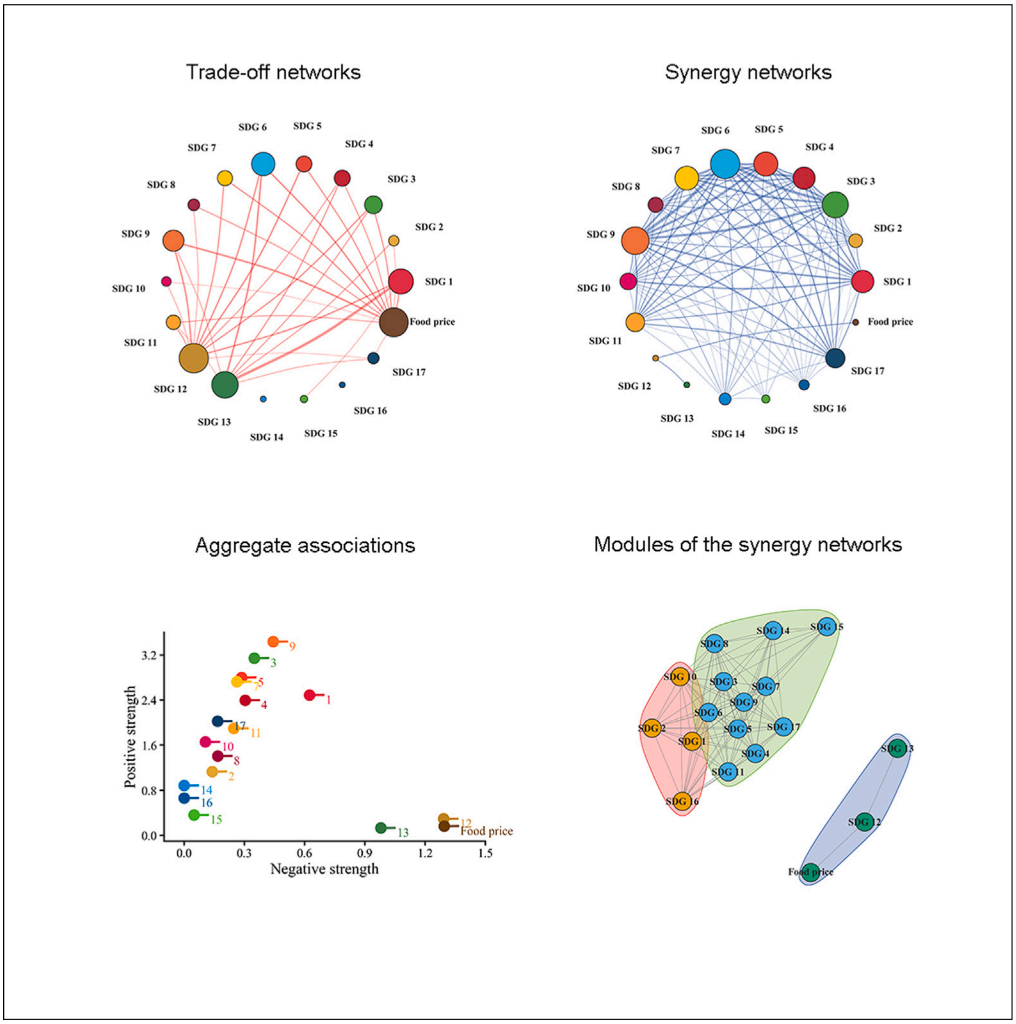
Assessing the role of global food commodity prices in achieving the 2030 agenda for SDGs



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Highlights

An upsurge in global food commodity prices entails trade-offs with 13 SDGs

Various extended analyses confirm the documented food price-SDGs nexus

Mitigating abrupt increases in food prices contributes to the fulfillment of SDGs

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Assessing the role of global food commodity prices in achieving the 2030 agenda for SDGs

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SUMMARY

Food plays a vital role in human sustenance and well-being, and the fluctuations in its price exert a significant impact on the attainment of the Sustainable Development Goals (SDGs) from social, economic, and environmental perspectives. This paper conducts an analysis utilizing data from 163 countries, revealing that an upsurge in global food commodity prices entails trade-offs with 13 SDGs, while exhibiting synergies with a few others. By considering specific food products, various types of countries, and the supply and demand shocks, further analysis confirms predominantly negative associations between spikes in food prices and the SDGs. Our findings highlight the urgent imperative to mitigate abrupt increases in food prices, such as those witnessed during the 2022 food crisis, to ensure the comprehensive fulfillment of the 2030 agenda for SDGs.

INTRODUCTION

The volatile international food prices have hit a record high in 2022 following a steep increase of 42% since 2020 (Figure S1). This surge can be attributed to significant global events, including the COVID-19 pandemic and the war in Ukraine, which have disrupted food supply chains and led to a decline in food production. Furthermore, it is highly likely that significant fluctuations in international food prices will persist in the coming years, primarily due to the more frequent occurrence of extreme weather conditions and their detrimental impact on food production.[1–3]

The rising cost of food has raised profound concerns among world leaders, as evident in the calls made during the G20 summit to ensure global food security.[4] These concerns stem from the recognition that food is a vital component of socio-economic well-being. High food prices can have far-reaching implications, extending beyond the immediate confines of the food industry to broader socio-economic realms, and posing a major threat to sustainable development. Indeed, various studies have highlighted the strong correlations between food prices and the achievement of Sustainable Development Goals (SDGs).[5–10]

The SDGs were a global initiative adopted by the United Nations member states in September 2015 with the central objective of promoting sustainable development and addressing critical global challenges. The ultimate aim is to eliminate poverty, safeguard the planet, and ensure prosperity for all by 2030. Global food commodity prices are intricately linked to the 2030 SDGs agenda, creating a web of interconnections among the varous SDGs. High food prices can lead to food scarcity, particularly affecting disadvantaged populations, thereby directly undermining SDG 2 (zero hunger) and SDG 3 (good health and well-being). Fluctuations in global food commodity prices can undermine the economic well-being of both food-importing and food-exporting countries (SDG 8), potentially widening the inequalities between countries (SDG 10). Moreover, inequalities within countries (SDG 10) might be exacerbated by rising food prices which disproportionately impact low-income households.[11] Consistent and sustained variation in agricultural prices, regardless of an increasing or decreasing trend, can result in unsustainable production and consumption practices (SDG 12).[12] Moreover, a surge in food prices may indirectly lead to the overexploitation and destruction of land-based and marine resources, as exemplified by the Sumatra deforestation case,[13] negatively affecting environmental SDGs such as SDG 14 (life below water) and SDG 15 (life on land).

Despite the complex interplay between food prices and the SDGs mentioned earlier, there is a dearth of literature providing a comprehensive investigation into how the changing food prices impede the achievement of the 2030 agenda for SDGs. To address this research gap, this paper makes a pioneering effort to systematically analyze the complex relationships between the global food prices movements and all 17 SDGs using correlational network analysis (for more details, see STAR Methods). Such an analytical approach employs graph theory to

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represent the relationships between variables as a network.[14,15] Studying the topology and drivers of networks could provide crucial insights into the complex systems between SDGs. Thereby, we can identify the hurdles and opportunities to maximize SDG implementation through various interactions.[14]

The analysis conducted in this paper examines the relationship between food prices and SDGs across 163 countries during the period 2000–2019. All 17 SDGs, encompassing 74 indicators, are considered in this study (Table S2). Our baseline results are based on the global food index from the Food and Agriculture Organization (FAO) and SDG indicators from the report series on sustainable development.[16,17] The latter database is widely utilized for tracking countries' progress toward the SDGs.

Furthermore, this paper undertakes comprehensive heterogeneous analyses. Firstly, it specifically assesses the impacts of four major grains (i.e., wheat, maize, rice, and soybeans) in international trade. Secondly, it examines variations between low- and high-income countries, as well as countries with differing levels of food self-sufficiency. Lastly, it disentangles the effects of food prices resulting from weather-induced supply shocks and aggregate demand shocks, considering the expected increase in extreme weather events due to climate change. These analyses help assess the possible transmission mechanisms of food prices changes on SDGs and evaluate the repercussions of policies that may affect food prices, such as agricultural trade policies and food security programs.[18]

RESULTS

The overall trade-offs and synergies between food prices and SDGs

This paper adopts the correlational SDG network analysis proposed by Lusseau et al.[14] to examine the role of food prices in achieving the SDGs. The topology of networks systematically unveils the interactive patterns between food prices and all 17 SDGs (for more details, see STAR Methods).

Figures 1A and 1B respectively depict the trade-off and synergy networks between food prices and the 17 SDGs. Edge width represents the magnitude of correlations between connected nodes, while node size refers to eigenvector centrality which implies the importance of each node in the correlational SDG network. Our analysis reveals that increases in food prices, as well as actions toward SDG 12 (sustainable consumption and production) and SDG 13 (climate action), could hinder the achievements of other SDGs, as shown in the trade-off networks. In particular, food prices spike exhibit negative interactions with 13 SDGs, especially those related to social and economic issues such as SDG 1 (no poverty), SDG 3 (good health), SDG 6 (clean water and sanitation), and SDG 9 (industry, innovation and infrastructure) (see Figure S2). As food is essential for human lives and well-being, the rise of food prices has far-reaching impacts on socio-economic activities. In contrast, the synergy network shows that food price increases have little structural importance, while actions toward SDG 1, 3, 6, 7 (affordable and clean energy), and 9 have compound positive effects on other SDGs (Figure 1B). Overall, our findings suggest that food price spikes may compromise the progress of many SDGs, and stable food prices are necessary to achieve the SDGs. Figure 1C shows the sum of positive and negative associations, and Figure 1D presents a modular analysis of the synergy network (for more details, see STAR Methods). These results further confirm the prevalence of trade-offs over synergies between food price hikes and SDGs.

Given that each single SDG contains several indicators, further investigation at the indicator level is required to provide more detailed insights into the relationships between food prices and the SDGs (see Figure S3; Table S2). Taking SDG 2 (zero hunger) as example, while the rise of food prices contributes to the achievement of SDG 2–4 (prevalence of obesity), it undermines the progress of the rest indicators of SDG 2, which yields the overall trade-off associations between food prices and SDG 2. Generally, the indicator-level analysis confirms that a surge in food prices induces more trade-offs than synergies. The most significantly harmful spillover effects involve indicators such as SDG 3–8 (life expectancy at birth), 2-2 (prevalence of stunting in children), and 1-1 (poverty headcount ratio at $1.90/day); the most beneficial spillover effects are for SDG 12-2 (nitrogen emissions embodied in imports) and SDG 2–4 (prevalence of obesity).

The primary trade-off associations between food prices spikes and the SDGs remain robust when examining the impact of specific grains in international trading, including wheat, maize, rice, and soybeans (see Figures S4–S7). The impacts of rice are relatively moderate due to its smaller trade volume in the global grain market. These findings are particularly relevant given the expected increase in extreme climate events and long-standing global uncertainties.[19] For instance, extreme droughts in Russia and Eastern Europe were the primary reason for the 30% increase in grain prices in 2010. The war in Ukraine has also destabilized global agricultural markets, resulting in a significant boost in wheat prices, as Russia and Ukraine produced 28% of the world's total wheat exports in 2020.[20]

Whether there is difference between different types of countries

This section presents a country-group analysis to explore whether the trade-off or synergistic associations between food prices and SDGs vary upon different income levels and food self-sufficiency rates of countries. All countries are classified into four groups based on their income level, as defined by the World Bank. Additionally, we provide another four-group categorization based on their food self-sufficiency rates (Table S3). Figure 2A shows the sum of positive (positive strength) and negative (negative strength) associations, and Figure S8 exhibits specific associations for each SDGs.

As shown in Figures 2A and S8, the dominance of trade-offs over synergies in the food prices-SDGs nexus remains consistent across different national income and food self-sufficiency levels. Even in countries with high income levels, the adverse associations between food prices increase and the SDGs are still notable, as evidenced by the recent living cost crisis fueled by inflation in Europe. The negative associations are also significant in countries with high food self-sufficiency rates and even in food-exporting countries, as these countries are

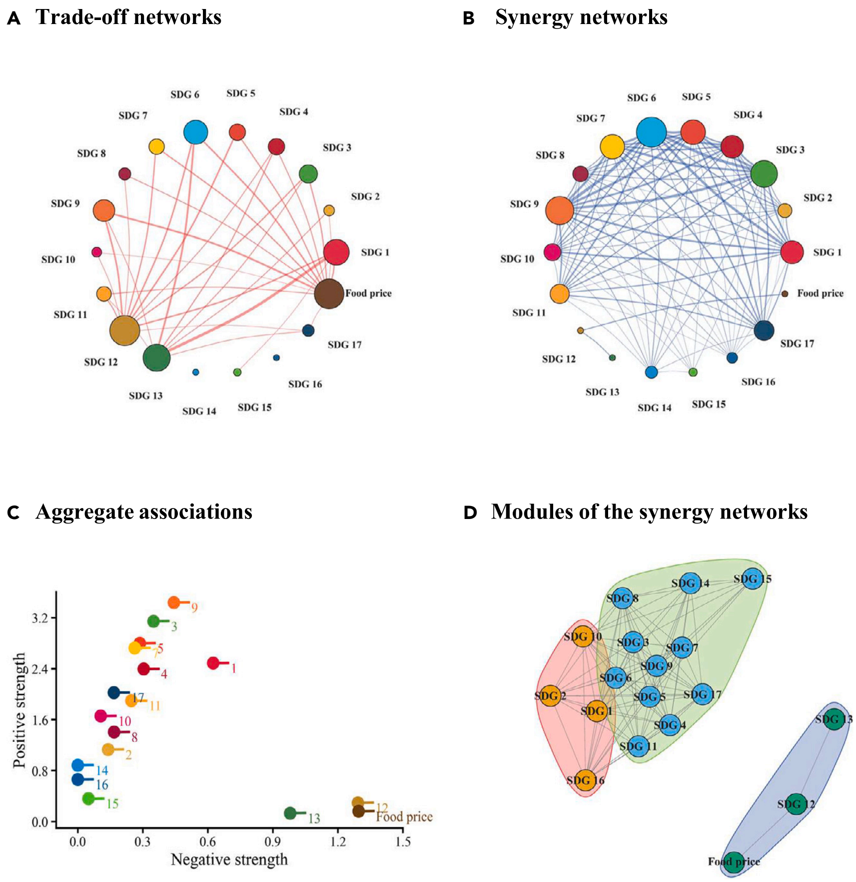

Figure 1. Trade-off and synergy networks

The nodes represent SDGs or food prices for all countries.

(A) Trade-off network. The network reflects the negative correlations between each SDG and the food prices. The size of a node corresponds to eigenvector centrality, highlighting the structural importance of each node in the network. The width of edges indicates the magnitude of correlations between connected nodes.

(B) Synergy network. The network reflects the positive correlations between each SDG and the food prices.

(C) Aggregate associations. The x axis represents the sum of negative correlations, and the y axis represents the sum of positive correlations.

(D) Modules of the synergy networks. A module represents a group of nodes that are highly connected among them and loosely connected to others. Different background colors represent different modules. Black lines represent SDG interactions in the module. For more details, see STAR Methods.

deeply integrated into the global market and experience significant pass-through of international food prices onto domestic prices.[21–23] Trade-offs are comparatively moderate for low-income countries, mainly due to the dominant role of the agriculture sector in their national economic structure, a significant percentage of total labor in the agriculture sector, and insufficient integration into the global food market.[24] Therefore, low-income countries, on average, are likely less sensitive to global food prices shocks.

Separating the effects of food prices caused by weather-induced supply and aggregate demand shocks

The volatility of international food prices can be attributed to either supply or demand factors and may lead to different impacts on the SDGs. To address this issue, this study separates out components of food prices fluctuations driven by weather-induced supply shocks and aggregate demand shocks and re-analyzes the network (for more details, see STAR Methods). Figure 2B reports the corresponding results, with the width of edges indicating the magnitude of correlations and the size of a node shows the structural importance of each node in the correlational SDG network.

Figure 2B suggests that there is no significant difference in the food prices-SDGs nexus given food prices fluctuations caused by supply or demand shocks. Food prices hikes triggered by aggregate demand shocks, which account for 29% of variations in food prices in the long run (Table S1), have significant adverse associations with twelve SDGs, such as SDG 2 and SDG 3. The results show that even the increase in food prices due to economic prosperity (e.g., the rising food prices due to economic booming during 2001–2007) can impede the achievement of SDGs. Food prices increases triggered by weather-induced supply shocks, which account for 39% of food prices fluctuations, also have significant negative impacts on nine SDGs, such as SDG 1. While the supply and demand shocks can explain most interactions between food

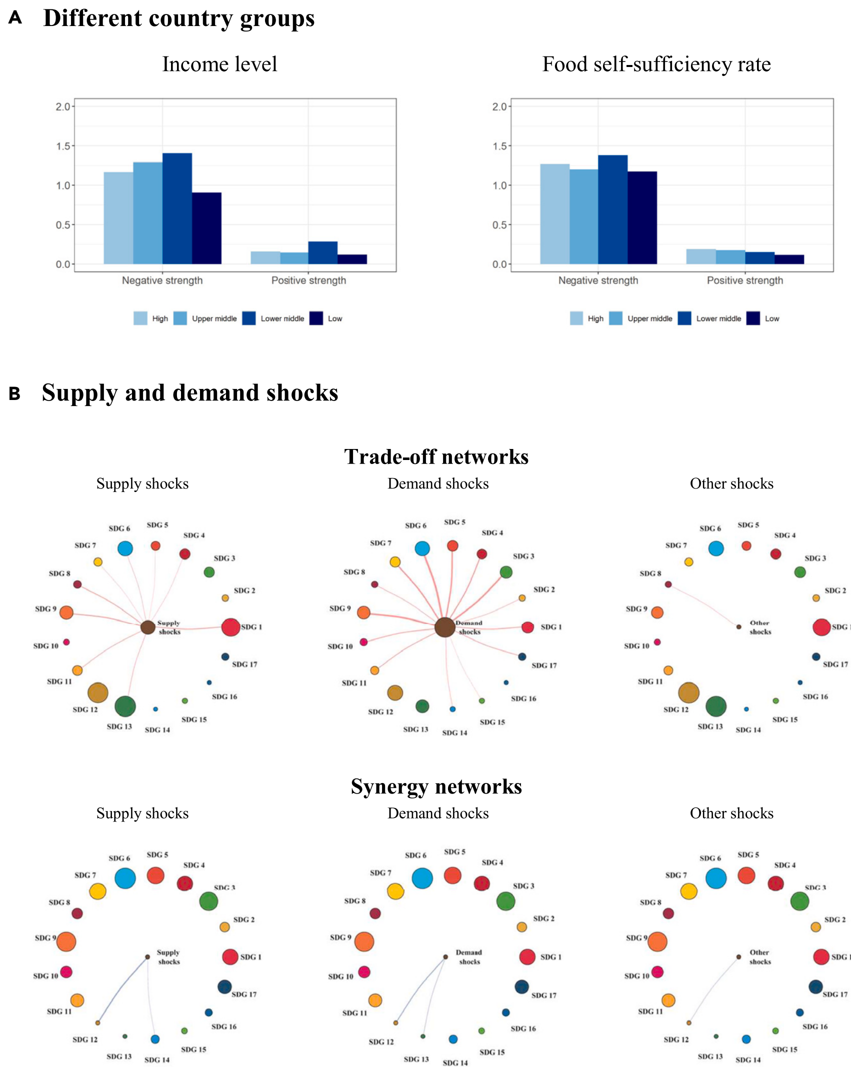

Figure 2. Heterogeneous effects across country groups and supply and demand shocks

(A) Different country groups. Sum of negative and positive correlations related to food prices across countries with different income levels and food self-sufficiency rates.

(B) Supply and demand shocks. Trade-off and synergy networks of food prices changes triggered by different types of shocks. The size of a node corresponds to eigenvector centrality, highlighting the structural importance of each node in the entire trade-off or synergy network. The width of edges indicates the magnitude of the negative or positive correlation between connected nodes. Components of food prices fluctuations driven by weather-induced supply shocks and aggregate demand shocks are estimated by the structural vector autoregressive model. For more details, see STAR Methods.

prices and SDGs, the rest components have little associations with SDGs. In summary, regardless of whether food prices increases are triggered by weather-induced supply shocks or aggregate demand shocks, they generally lead to more trade-offs than synergies in relation to the attainment of SDGs.

DISCUSSION

This study sheds light on the overall relationship between global food commodity prices increases and all 17 SDGs, utilizing data from 163 countries. It pioneers research in the domain of sustainable development by specifically focusing on food prices. Our analyses reveal that increasing food prices have direct and immediate implications for the attainment of SDG 1 (no poverty), SDG 2 (zero hunger), and SDG 3 (good health) (Figure S2). The results also suggest that overall increases in food prices have trade-offs with 13 out of 17 SDGs while showing synergies with a few others (Figure 1A). Although our results indicate that the overall negative impacts are similar across countries of different income levels (Figure 2A), disadvantaged population in a particular country are likely to suffer more severely from rising food prices, given their limited capacity to mitigate the impact of food prices spikes on their daily lives.[11]

The nexus between food prices and SDGs revealed in this study underscores the urgent need for academic and practical efforts to mitigate sharp surges in food prices, such as those observed in the 2022 food crisis. These efforts substantially benefit the overall achievement of global sustainable development by the 2030 deadline. As significant fluctuations in food prices are anticipated to persist in the coming years due to increasing extreme climate events and long-standing global uncertainties (e.g., the ongoing war in Ukraine), we draw three policy implications from this study regarding the impacts of food prices on the realization of SDGs.

First, developing an early warning system

It is crucial to establish an early warning system that can detect the initial signs of food prices spikes. This can be achieved by enhancing data collection and monitoring systems, specifically focusing on the impact of extreme climate events and food supply shocks on food prices. By closely monitoring these factors and their consequences for sustainable development, governments and international organizations can respond promptly to prevent or mitigate adverse effects. To gain a comprehensive understanding of the transmission mechanisms of food prices and their impact on SDGs, monitoring efforts should be expanded to include more timely and detailed retail data from a broader range of market locations and countries.

Second, mitigating challenges posed by food prices spikes

Governments should implement measures to stabilize food markets in the short run. This can involve establishing strategic food reserves and implementing price control policies to mitigate sudden price spikes and ensure a consistent food supply. Additionally, it is important for governments to establish or strengthen social safety nets that protect vulnerable populations during periods of rising food prices. These safety net programs should be carefully designed to ensure access to affordable and nutritious food, with a particular focus on low-income and disadvantaged communities.

Third, fostering international cooperation and coordination

Given that the impacts of food prices fluctuations extend beyond national borders, it is imperative to promote international cooperation and coordination. Regular dialogues between food producers and consumers should be facilitated to maintain global supply chains and stabilize food prices, especially during times of market chaos. Furthermore, international cooperation is crucial to encourage investment and technology transfer in agriculture, particularly in developing countries. Such support can help boost food production and contribute to stabilizing prices on a global scale.

Limitations of the study

Despite the insightful analyses presented in this study, several limitations should be acknowledged. Firstly, while the results reveal the existence of associated synergistic co-benefits and trade-offs between global food commodity prices spikes and the 17 SDGs, this study falls short of establishing a causal relationship. Secondly, the analysis does not incorporate domestic retail prices data, which is due to lack of reliable data with a long time span for the statistical analysis.[19,23] Instead, the estimating correlational results capture the average transmission magnitude of international prices into local prices.[25] The scope of this investigation does not permit a detailed examination of individual countries, potentially limiting a more comprehensive understanding of the food prices-SDG nexus at the domestic level. However, our study suggests a crucial direction for future research, namely, to connect local prices spikes with rapidly advancing national or subnational SDG indicators[26,27] using our analytical framework and considering country-specific situations.

STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

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SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.isci.2024.108832.

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AUTHOR CONTRIBUTIONS

Conceptualization, Y.S., Y.Q., and X.S.; methodology, Y.S. and Y.C.; formal analysis, Y.S., Y.A., and Y.C.; investigation, Y.S., X.S., Y.A., and Y.C.; data curation, Y.A. and Y.C.; writing – original draft, Y.S., Y.Q. M.Y., and X.S.; writing – review & editing, Y.S., Y.Q., X.S., M.Y., and Y.C.; funding acquisition, Y.S. and X.S.; supervision, Y.S. and X.S.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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STAR★METHODS

KEY RESOURCES TABLE

REAGENT or RESOURCE	SOURCE	IDENTIFIER
Deposited data		
SDG indicators	Sustainable Development Report 2022	https://www.sustainabledevelopment.report/reports/sustainable-development-report-2022/
FAO Food Price Index	Food and Agriculture Organization (FAO)	https://www.fao.org/worldfoodsituation/foodpricesindex
The annual real prices of wheat, rice, maize and soybeans	World Bank pink sheet	https://www.worldbank.org/en/research/commodity-markets
The proxy of global real activity	Kilian (2009)[28]	https://www.aeaweb.org/articles?id=10.1257/aer.99.3.1053
The global weather and harvest shocks	De Winne and Peersman (2021)[19]	https://doi.org/10.1038/s41558-021-01102-w
Software and algorithms		
R 4.2.1	R Core Team, 2022	https://www.r-project.org/
Python 3.9.12	Python Software Foundation	https://www.python.org/

RESOURCE AVAILABILITY

Lead contact

Further information and requests for resources should be directed to and will be fulfilled by the Lead Contact, Xunpeng Shi (Xunpeng.Shi@uts.edu.au).

Materials availability

This study did not generate new materials.

Data and code availability

- Data: This paper analyzes existing, publicly available data. These accession numbers for the datasets are listed in the key resources table.
- Code: All custom code can be available on request from the lead contact.
- Any additional information required to reanalyze the data reported in this paper is available from the lead contact upon request.

METHOD DETAILS

Network method

We used Pearson correlation coefficients to measure the associations between each pair of indicators[15,29]: A positive value represents a synergy whereas a negative value represents a trade-off, and the absolute value of the correlation coefficient represents the magnitude of the associations. Before estimating the correlation coefficients, we centered indicators on their mean within each country and scaled by their variance. By doing so, we are able to avoid the possible omitted variable bias caused by the country-specific features such as GDP per capita, urbanization, and population density. Resulting correlation coefficients significantly different from zero (with < 0.05) were retained to estimate the network, which is a 75×75 ($i \times j$) matrix for indicators and a 18×18 ($i \times j$) matrix for SDGs (including food price growth). The correlation coefficients were converted to a network graph object and analyzed by R with the *igraph* package. To facilitate the interpretation of the results, the networks for positive (synergies) and negative (trade-offs) correlations were calculated separately. Three key network metrics of *centrality*, *strength* and *module* are investigated to reveal the role of food price in achieving the SDGs.

We estimated the eigenvector centrality of each node in its respective networks. The eigenvector centrality provides a measure of the relative contribution of a goal/indicator to the overall topology of the network. A goal with large eigenvector centrality will have large indirect effects on other goals, not only those with which it is associated, but also effects propagating through its neighbors. Hence, it provides an integrated estimate of the overall weight of a goal in shaping the fate of all goals. Strength is a measure of the sum of associations between a goal and the goals with which it is directly associated; The more a goal has connection, the larger its strength. As we have both positive and negative associations, we estimated the positive strength and negative strength. Goals with large negative strength and small positive strength will tend to be a hindrance for other goals, and vice versa. Module measures group of nodes highly connected among them and loosely connected to others, according to the cluster *walktrap* algorithm. In particular, in the synergy networks, components in each module show strong synergies among them and are likely to be achieved simultaneously.

Historical decomposition of food prices

It is also of interest to differentiate between the effects of demand and supply shocks in commodity markets when one attempts to assess the socioeconomic impacts of commodity shocks. Therefore, we experimented to adopt a structural vector autoregressive (SVAR) model[28] with global weather and harvest shocks constructed by De Winne and Peersman (2021)[19] to further decompose the movements of food price into components triggered by three structural shocks: (1) weather-induced supply shocks (supply shocks); (2) global real activity that affects the demand for commodities (aggregate demand shocks); (3) shocks that are not captured by factors specified above (other shocks). In particular, we used quarterly data for $\mathbf{z}_t = (prod_t, rea_t, rpf_t)'$, where $prod_t$ is a set of weather-related global food supply shocks, rea_t denotes the index of real economic activity, and rpf_t refers to the real price of food. The time span covers from 1973 to 2016 due to the data availability of weather-related global food supply shocks provided by De Winne and Peersman (2021). The SVAR representation is

$$\mathbf{A}_0\mathbf{z}_t = \boldsymbol{\alpha} + \sum_{i=1}^{8} \mathbf{A}_i\mathbf{z}_{t-i} + \varepsilon_t,$$

where ε_t denotes the vector of serially and mutually uncorrelated structural innovations. We postulate that $\mathbf{A}_0^{-1}$ has a recursive structure such that the reduced-form errors $\mathbf{e}_t$ can be decomposed according to $\mathbf{e}_t = \mathbf{A}_0^{-1}\varepsilon_t$:

$$\mathbf{e}_t \equiv \begin{pmatrix} e_t^{prod} \\ e_t^{rea} \\ e_t^{rpf} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{\text{supply shock}} \\ \varepsilon_t^{\text{aggregate demand shock}} \\ \varepsilon_t^{\text{other shock}} \end{pmatrix}.$$

This model postulates the weather-induced supply shocks are not affected by two other shocks in the short run. Shifts of the aggregate demand curve result in an instantaneous change in the real price of food, as do unanticipated food supply shocks that shift the supply curve. Based on the estimated SVAR model, we are able to conduct the standard forecast error variance decomposition (Table S1) and historical decomposition (Figure S9) analysis. After separating out supply and demand components in food price series, we reanalyzed the network introduced above to examine the heterogeneous SDG impacts of food price fluctuations driven by supply or demand shocks. Our results are robust when we used the alternative harvest shocks to proxy the food supply shocks (Figure S10).

QUANTIFICATION AND STATISTICAL ANALYSIS

All quantification and statistical analyses were performed as described in the method details section of the STAR Methods.