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Impact of Energy Disruptions on Agri-food Supply Chains

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Abstract

The blockade of the Strait of Hormuz has triggered a global energy supply shock, posing a serious threat to agriculture and food systems. However, the specific mechanisms for the damage to food security and rural livelihoods in developing countries have not been fully studied. Using the hypothetical extraction method (HEM) and the input-output data of the Asian Development Bank (ADB), we quantify the impact of such serious oil supply interruptions on the output, value-added, and employment multiplier of agricultural and food supply chains in India, Pakistan, and the Philippines. By breaking down the multiplier into direct, indirect, and induced channels, we find that the structural vulnerabilities of these developing countries are mainly driven by induced effects. The contraction of labor income and household consumption is the main reason for the contraction of total output, which shows that the main threat to food security is not only the shortage of real production but also the systematic collapse of household purchasing power. In addition, the transnational decomposition of downstream and upstream supply chain sectors reveals profound structural heterogeneity, emphasizing that the transmission of energy shocks will change with different upstream and downstream dependencies. In order to effectively mitigate these asymmetric shocks, crisis response strategies must go beyond traditional physical supply indicators. Policymakers should integrate food rights frameworks, active income stabilization measures, and diversified supply chains to guarantee human livelihoods and ensure fair access to food.

Keywords: Energy shock; Hypothetical extraction method; Agri-food supply chains; Food security

Introduction

The conflict in Iran that broke out in 2026 triggered a serious global energy turmoil. The crisis constitutes a structural fracture of the global agricultural and food system (Glauber 2026; Shokri 2026). During the war, Iran took measures to block the Strait of Hormuz, which carries nearly 27% of the world's oil exports, 20% of liquefied natural gas (LNG) exports, and about 30% of the core fertilizer raw material trade (Glauber 2026; Usanmaz 2026). After Iran blocked the Strait, the supply interruption of the global petrochemical industry quickly triggered a chain reaction in global energy and fertilizer prices. The price of Brent crude oil has exceeded $100 per barrel; the Northern Hemisphere is facing a serious shortage of nitrogen fertilizer (Glauber 2026; Partridge 2026) during the critical spring cultivation period, and global and regional food security is facing an unprecedented compound threat. The current geopolitical crisis is pressing, and most existing research views the relationship between energy and food from a narrow price transmission perspective, generally assuming that rising energy costs will drive up food prices and lead to production shortages (Darwez et al., 2023; Asadollah et al., 2024). This supply-oriented analysis ignores deeper economic transmission paths. As Sen (1983) emphasized, food security crises stem more from the collapse of household purchasing power than from mere material shortages. Developing Asian economies such as India and Pakistan, whose agricultural and food supply chains are highly dependent on energy-intensive imports and whose low-income labor groups are vulnerable to shocks, are typical examples of studies on energy shock vulnerability (Munir et al., 2022; Xue et al., 2025). However, evidence is still lacking to demonstrate how the vulnerability of agricultural and food supply chains transforms from energy shortages to livelihood threats under extreme shocks such as the closure of the Strait of Hormuz.

To address this issue, this study conducts a crisis response analysis based on input-output data from the Asian Development Bank, simulating a scenario of energy supply disruption caused by a closure of the Strait of Hormuz. Using a hypothetical extraction method, we decomposed the total output loss caused by this geopolitical crisis into direct, indirect, and induced effects. Through analysis, we quantified the extent of damage caused by industrial disruption and consumption contraction under different transmission pathways and revealed the deep-seated mechanisms by which the energy crisis is transmitted to household consumption through the agricultural and food supply chain, threatening food security and human livelihoods.

Literature Review

Existing empirical studies generally agree that energy price shocks are transmitted to the food system through multiple channels and have a significant impact. Asadollah et al. (2024) estimated that global supply chain disruptions can explain about 22% of food inflation fluctuations, with oil price shocks contributing as much as 55%

to the transmission of energy-related prices. This transmission effect exhibits significant asymmetry in oil-dependent economies: Darwez et al. (2023) found that a 1% increase in international oil prices would lead to a long-term increase of 0.32% in domestic food prices in Saudi Arabia, while a 1% decrease in oil prices would only reduce food costs by 0.25%. This downward rigidity mainly stems from the concentration of market forces and the structural dependence of aggregate demand on oil-related government revenue. Furthermore, supply chain diversification can increase an economy's ability to withstand mild to moderate food shocks by 15%, which also highlights the vulnerability of economies reliant on a single supply corridor to energy shocks (Davis et al. 2021). While these studies explain the relationship between the energy and food systems in terms of price dynamics, they do not explore how energy disruptions structurally alter the productive capacity and employment in the agri-food sector.

Broader political economic research offers a deeper structural perspective. McMichael (2009) used a food system framework to analyze the 2007-2008 global food crisis, arguing that it was not a market accident but a structural consequence of fossil fuel dependence, agribusiness consolidation, and neoliberalism, placing agriculture under global value relations. His analysis shows that the food-fuel complex systematically erodes the social reproduction conditions of vulnerable groups, and rising costs combined with monopolistic pricing lead to a purchasing power crisis among the world's poor. This insight directly echoes Sen's (1983) entitlement theory, which posits that hunger stems from the failure of exchange rights based on production, trade, and labor, rather than a shortage of aggregate supply.

Methodologically, the hypothetical extraction method (HEM) provides a suitable tool for quantifying these structural dynamics. Unlike traditional demand-oriented models, the HEM can simulate economic contractions in specific sectors and measure their impact on the overall economy (Dietzenbacher and Lahr 2013). When the Leontief model is combined with the link between household income and consumption, the HEM can decompose the impact into direct, indirect, and induced channels (Ali et al. 2019). Boylan et al. (2020) advocated applying this decomposition method to food systems analysis. However, no studies have yet applied it to quantify how energy disruptions cascade through the agri-food sector in developing economies, nor have they separately analyzed the dominance of the purchasing power channel as indicated by McMichael's (2009) food systems analysis and Sen's (1983) rights theory. This paper, therefore, examines the dominant pathway of energy-shock vulnerability in Asian agri-food systems.

Methods

This study adopts the hypothetical extraction method (HEM) and is based on the demand-driven Leontief input-output framework (Miller and Blair 2009; Dietzenbacher and Lahr 2013). All data come from the Asian Development Bank in 2024, covering India, Pakistan, and the Philippines. This study assumes that the energy sector of the above countries is partially disrupted, to estimate their vulnerabilities.

$\mathbf{Z}$ represents the inter-industry flow matrix of n × n, $\mathbf{f}$ is the vector of final demands, and $\mathbf{x}$ is the total output vector. The accounting identity $\mathbf{x} = \mathbf{Zs} + \mathbf{f}$ (where $\mathbf{s}$ is a full 1 vector) derives the direct requirements matrix $\mathbf{A} = \mathbf{Zx}^{-1}$, with a typical element $a_{ij} = z_{ij}/x_j$, representing the intermediate input from sector i per unit of output in sector j. The standard open Leontief model relates total output to final demand as:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{f} = \mathbf{L}\,\mathbf{f} \tag{1}$$

where $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse. Its element l_{ij} captures the total output required from sector i to deliver one unit of final demand in sector j.

Considering the household income, $\mathbf{A}$ is added a labor-income row of the wage coefficient vector $\mathbf{h}_n$ and a household-consumption column of the expenditure propensity vector $\mathbf{h}^c$, forming the augmented coefficient matrix $\bar{\mathbf{A}}$. The augmented system is:

$$\bar{\mathbf{x}} = (\mathbf{I} - \bar{\mathbf{A}})^{-1}\,\bar{\mathbf{f}} = \bar{\mathbf{L}}\,\bar{\mathbf{f}} \tag{2}$$

where $\bar{\mathbf{L}}$ is the augmented Leontief inverse. The HEM simulates the partial interruption of the petroleum refining sector (sector k). The sector's intermediate deliveries to all other sectors are reduced by a fraction α ($0 \le \alpha \le 1$), while its production technology (the k-th column of $\mathbf{A}$) remains unchanged. The post-extraction coefficient matrix is: $\bar{\mathbf{A}}^* = \bar{\mathbf{A}} - \alpha\mathbf{e}_k\mathbf{b}'_k$, where $\mathbf{e}_k$ is the k-th unit vector and $\mathbf{b}'_k=(a_{k1},\ldots,a_{k,k-1},0,a_{k,k+1},\ldots,a_{kn})$ is the k-th row of $\bar{\mathbf{A}}$ with the diagonal element of all zeros. The post-extraction Leontief inverse is therefore represented as follows:

$$\bar{\mathbf{L}}^* = \bar{\mathbf{L}} - \frac{\alpha\bar{\mathbf{L}}\mathbf{e}_k\mathbf{b}'_k\bar{\mathbf{L}}}{1+\alpha\mathbf{b}'_k\bar{\mathbf{L}}\mathbf{e}_k} \tag{3}$$

For a specific element (i, j), the change in the augmented Leontief inverse is expressed as:

$$\Delta \bar{l}_{ij}=\bar{l}^{*}_{ij}-l_{ij}=\frac{-\alpha l_{ik}\left[(1-a_{kk})l_{kj}-\delta_{kj}\right]}{1+\alpha[(1-a_{kk})l_{kk}-1]} \tag{4}$$

When the partial extraction also reduces final demand proportionally ($\bar{f}_k=(1-\alpha)f_k$), the change in gross output of sector i becomes: $\bar{x}^{*}_i-\bar{x}_i=-\tilde{\lambda}_k \cdot l_{ik}$, where:

$$\tilde{\lambda}_k=\frac{\alpha(1-a_{kk})x_k}{1+\alpha((1-a_{kk})l_{kk}-1)} \tag{5}$$

The change in total value added follows as:

$$\Delta VA=\sum_i v_i(\bar{x}_i-x_i)=-\tilde{\lambda}_k\sum_i v_i l_{ik}=-\tilde{\lambda}_k \cdot \mu_k \tag{6}$$

v_i is the value-added coefficient, value added per unit of gross output, and μ_k is the Type II value-added multiplier for sector k. Similarly, employment impacts are computed by replacing v_i with the employment coefficient e_i.

All multiplier values are reported per $1 million change in final demand of the chosen sector j. Each post-extraction multiplier is decomposed into three effects: (i) the direct effect (unity), (ii) the indirect effect (Type I multiplier derived from the standard open model **L**, minus unity), and (iii) the induced effect (Type II minus Type I multiplier). Thereby, the dominant transmission pathway of the energy shortage can be identified.

Findings

Impacts on upstream sectors

Fig. 1 shows the decomposition of the total output multipliers of upstream sectors in the agri-food supply chains of India, Pakistan, and the Philippines under energy shock scenarios. The total output multiplier level measures the ability of each sector to contribute to total output in the economy. The upstream sectors are classified following Ahmad and Alvi (2024), which include supplying essential production inputs to food production. Agriculture provides essential inputs for food; chemicals supply fertilizers, pesticides, agrochemical inputs, coke, and petroleum are core energy inputs for agricultural mechanization, fertilizer production, irrigation, and key materials for fishing.

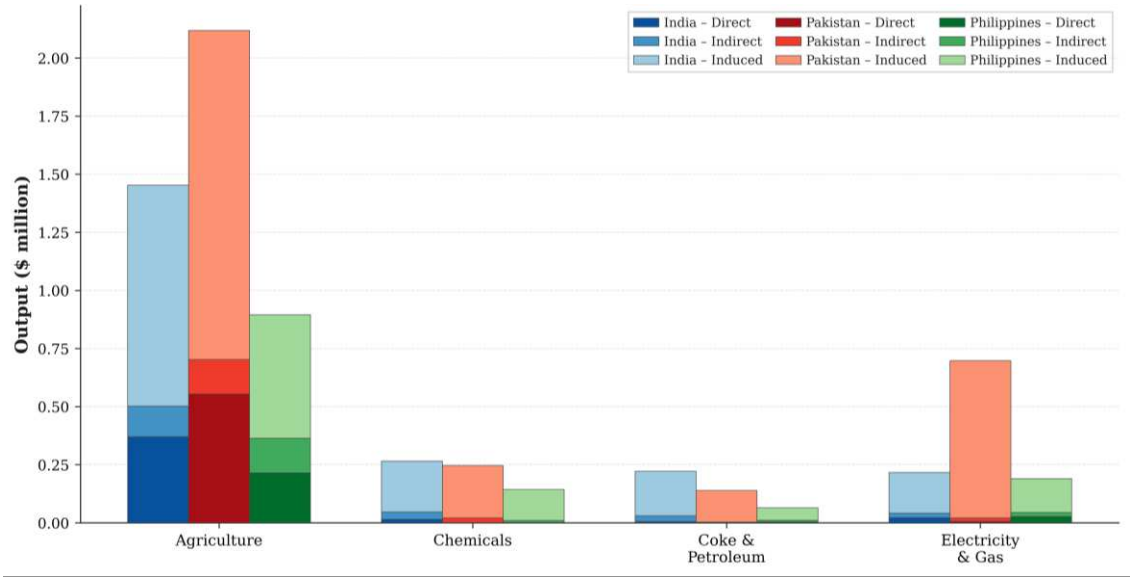


Fig. 1 Upstream sector output decomposition under energy disruption

Under the energy supply shock, the agriculture sector generates the largest output multipliers across three countries, and Pakistan has the highest. A 1% increase in total demand would increase the total output by 2.12% in Pakistan, compared with 1.45% in India and 0.90% in the Philippines. The agriculture sector contributes more to economic growth in Pakistan than in India and the Philippines. The highest multiplier of Pakistan is mainly due to its higher direct and indirect effects. A higher direct effect means that Pakistan's agricultural productions are sensitive to energy inputs. If the energy inputs expand, then the agricultural output in Pakistan will increase more rapidly. However, if

the energy shortage in Pakistan becomes more severe, then the agricultural sector will be damaged quickly. The higher induced effect indicates that the agriculture sector is the major engine for household consumption, making Pakistan's overall economy more vulnerable to energy shocks along the agriculture supply chain. In comparison, the Philippines has the smallest total multiplier originating from its lower induced effect. This reflects the weaker income-consumption circulation in the Philippines. The agricultural income cannot be effectively transferred into wider domestic consumption, indicating potential economic leakages and weaker cross-sector integration. India's moderate total multiplier reflects a more balanced and diversified economic structure. With a higher level of domestic consumption driven by agriculture and sufficient economic diversification, India can buffer the energy shocks to the whole economy.

In the chemical sector, the total multiplier is small, and the induced effects exceed 80% of the total effect. In three economies, this sector is an industrial island with high import dependence. The contribution of the chemical industry to economic growth is heavily reliant on payments to employees transferred into household consumption. As the direct shock source defined in the HEM, the energy sector is the lowest in all upstream sectors across the three countries. The energy sectors of India, Pakistan, and the Philippines are capital-intensive and import dependent. The lockdown of the Strait of Hormuz could hinder the production cycle of downstream high-multiplier engines along the agri-food supply chain.

Impacts on downstream sectors

Fig. 2 contains the decomposition of total output multipliers of downstream sectors along the agri-food supply chain. The downstream sectors originate from the previous research of Ahmad and Alvi (2024). The food and beverage sector is the core processing stage that transforms agricultural raw materials into consumer goods. Inland transport moves goods from farms and factories to markets. Wholesale and retail trade coordinate the distribution channels of food, delivering to end consumers. The hotel and restaurant industries represent the buyers of goods produced.

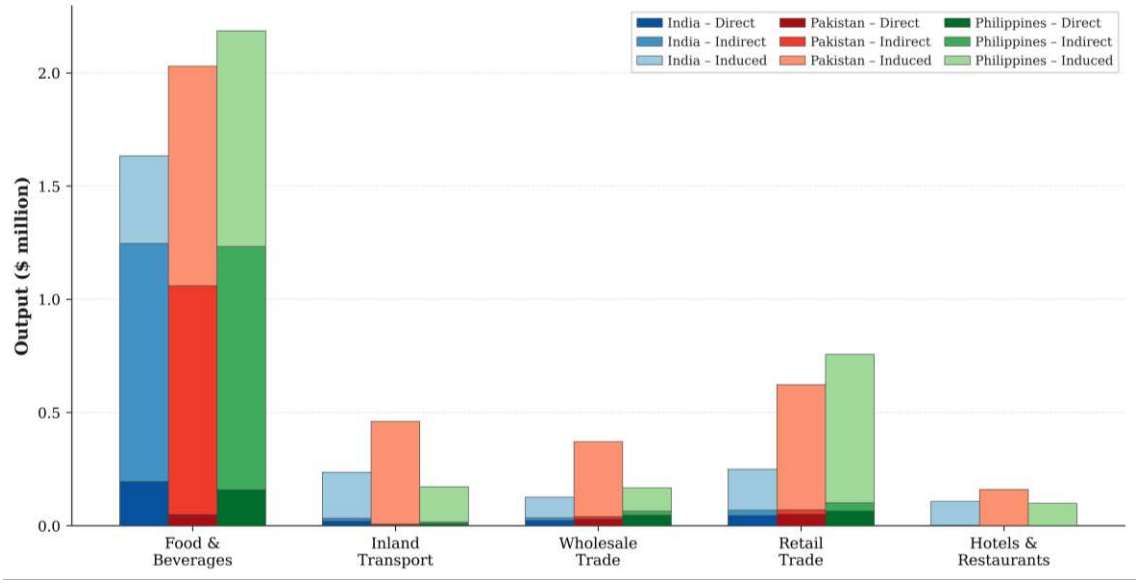


Fig.2 Downstream sector output decomposition under energy disruption

Different from the agriculture sector, the indirect effects dominate the total effects across three countries in the food sector in the energy shortage scenario. The difference reveals the nature of the core hub of the food sector in the agri-food supply chain. Under energy shock, the influence on the food sector mainly comes from the cumulative costs along the agri-food supply chain, rather than the direct energy costs of the food sector. As the energy costs increase, the food sector would transmit the shock along the supply chain by reducing the intermediate purchases rather than through the household income-consumption cycle. To maintain food stability, policymakers should not only notice the dependence on energy of the food sector but also the entire costs along the agri-food supply chain. One interesting thing is that the share of the induced effect accounts for 48% of the total effect in Pakistan and 44% in the Philippines, much higher than India's 24%. The household purchasing power plays a more important role in sustaining food processing output in Pakistan and the Philippines, making them more vulnerable to wage contraction

than India.

For the other downstream sectors, the induced effect re-emerges as the key transmission channel, similar to the upstream sectors. This indicates the high labor-intensive characteristics of these sectors. Their contributions to the total output depend a lot on maintaining employment and the corresponding income-consumption circular. Under energy shock, the breakdown of these sectors would damage the macroeconomy in forms of large-scale unemployment and a decline in the real wage rate. Given the fact that low-income workers are most employed in informal food retail and hospitality, the energy-induced compression of wages contracts these sectors first, threatening the livelihoods of the most vulnerable groups (Amaglobeli et al. 2023; ILO 2024).

The structural differences among these sectors are obvious. Pakistan has a higher total output multiplier in inland transport, wholesale trade, and hotels and restaurants, exposing its highly sensitive distribution networks. Energy shocks would be amplified across these bottleneck processes and induce systematic economic decline. India has a medium-level total output multiplier due to its more formalized logistics infrastructure that can partially buffer against rising energy costs and a larger geographical size that provides a bigger domestic market. The retail trade of the Philippines has the highest total multiplier compared with India and Pakistan, which is also the highest multiplier in the other four downstream sectors, indicating that the most vulnerable part of the Philippines is at the end of the agri-food supply chain. During the energy crisis, ensuring the retail department and the purchasing power of end consumers is vital for stabilizing the entire economy of the Philippines.

Impacts on value-added and employment

Table 1 reports the value-added and employment multipliers under baseline and oil-supply-disruption scenarios, where the induced share is the proportion of induced effects in terms of total effects. Across all three countries, a consistent pattern emerges: the induced channel accounts for the largest share of value-added generation. In India, the post-shock induced share reaches 77.5% of total value added (VA) through the food and agriculture sectors, respectively. Under the oil supply disruption scenario, these figures shrink to $3.68 million and $4.22 million, respectively. The post-shock induced effect accounts for 77.5% of the VA, indicating that the value creation process is highly dependent on the cyclical transmission mechanism formed by labor income and household consumption. Pakistan has an even higher induced effect ratio of 80.3%. Of the $4.56 million in VA generated in its food sector after the shock, $3.66 million was generated through induced channels. The Philippines exhibits a highly consistent structural characteristic, with an induced effect ratio of 73.4%. This cross-national consistency suggests that the macroeconomic losses caused by energy shocks are essentially a purchasing power crisis. Declining household income leads to a gradual contraction in consumption expenditure, thereby weakening the endogenous demand supporting overall economic value creation.

Table 1 Value-added and employment decomposition

Country	Sector	Direct	Indirect	Induced	Total	Baseline	Induced Share
Panel A: Value Added ($m)							
India	Agriculture	0.8143	0.1374	3.2733	4.2249	4.7587	77.50%
India	Food	0.1452	0.6834	2.85	3.6787	4.1833	77.50%
Philippines	Agriculture	0.5064	0.3524	2.373	3.2318	3.3134	73.40%
Philippines	Food	0.3335	0.4879	2.2695	3.0909	3.1749	73.40%
Pakistan	Agriculture	0.7346	0.2108	3.8558	4.8012	5.125	80.31%
Pakistan	Food	0.2258	0.6717	3.6603	4.5578	4.8698	80.30%
Panel B: Employment (persons)							
India	Agriculture	254	25	474	754	828	62.90%
India	Food	22	161	413	595	665	69.40%
Philippines	Agriculture	133	64	249	447	454	55.70%
Philippines	Food	16	73	238	328	336	72.60%
Pakistan	Agriculture	188	45	624	858	911	72.73%
Pakistan	Food	51	152	592	795	846	74.50%

Further job decomposition results provide clearer empirical evidence for food security analysis. In India, the shock reduced jobs per million USD of agricultural demand from 828 to 754, and in the food sector from 665 to 595. These losses spread beyond agriculture into retail, transportation, and services. In Pakistan, food sector jobs decreased from 846 to 795, with 74.5% of the job creation coming from household consumption, confirming that employment in the

agricultural and food sectors is highly dependent on household consumption channels. In the Philippines, agriculture maintained a high level of direct employment after the shock, yet 72.6 percent of the total employment multiplier in the food processing industry remains driven by induced effects rather than direct hiring. Notably, job losses were primarily concentrated in rural areas. Since food expenditure dominates local household budgets, income declines can easily push vulnerable households below the food poverty line.

Value-added and employment multiplier decomposition further support a possible risk transmission path. The supply shock of energy disruption first enhances price fluctuations and increases agricultural input costs through direct effects, then these costs are indirectly transmitted through interrelated linkages among industries, and ultimately exerts a dominant induced effect by compressing household wages and consumer demand within the production network. This type of structural contraction shock has an asymmetric negative impact on low-income groups, whose purchasing power continues to decline, making food prices, driven by rising production costs, even more unaffordable. This self-reinforcing vicious cycle suggests that energy and food security assessments need to move beyond traditional supply-side indicators and focus more on the systemic erosion of households' access to food.

Conclusion

This study analyzes the transmission paths and mechanisms of energy supply shocks to the agri-food systems. The results of the HEM and decomposition indicate that the induced channel is the most important transmission across three economies in the upstream sectors under energy shocks, as household income contracts, consumption declines, and the output-generating capacity of input-supplying sectors erodes. In the downstream sectors, indirect linkages with other sectors dominate the output contribution of the food sector, while the induced effect accounts for most of the total output multiplier in India, Pakistan, and the Philippines. The reduction in intermediate procurement in the food sector would transfer the impact of the energy shock across the agri-food supply chain, while the induced consumption contraction in other downstream sectors would further damage the economy. The value-added and employment multipliers indicate that the induced effect accounts for 77.5%, 80.3%, and 73.4% for the total multipliers of India, Pakistan, and the Philippines, respectively. In the labor market, every $1 million decline in the total demand would lead to a 25 to 161-person decline in employment. The low-income groups mainly work in agri-food-related sectors, and they could suffer a lot. Their purchasing power would be further eroded due to the loss of jobs.

Cross-national comparative analysis reveals that the vulnerability of the agri-food supply chain varies across three countries. India has a relatively stronger buffer capability due to its diversified economic structure compared with Pakistan and the Philippines. Pakistan faces higher risks in the agriculture sector and the distribution networks. The Philippines is most vulnerable in the retail trade and the end consumption process. Traditional crisis policies often focus on oil, fertilizer, food reserves, and logistical support to ensure the stability of the food supply. However, this is not sufficient when considering the weakening access to food of low-income families. Policymakers should coordinate energy security, food security, and social protection policies, prioritizing measures such as cash transfers, rural employment support, and targeted food subsidies, while ensuring a stable supply of key inputs and logistics systems, to prevent low-income families from falling into food inaccessibility due to income losses.

This study has certain limitations, which also point the way for future research. The study uses a static input-output framework, which cannot capture the energy substitution effect in the long term. The HEM only simulates the proportional reduction of output, failing to fully reflect the refined logistical constraints under scenarios such as the closure of the Strait of Hormuz. Future research could introduce computable general equilibrium models to expand the analytical framework, incorporate price-induced substitution effects, and conduct in-depth analysis at the distribution level using sub-national household survey data. By examining the temporal dynamics of multiplier adjustments, quantitative research on the energy-food relationship can be further combined with the political and economic analysis of food systems, providing more rigorous empirical support for research related to food equity.

Declarations

Author contributions

Ren involves in paper writing and analysis. Yong contributes to idea development, methodology and paper refinement.

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Data availability statement

No datasets were generated or analyzed during the current study.

Competing interests

The authors declare no competing interests.

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