

Reviewer #1: The manuscript presents a comprehensive and methodologically robust analysis of the role of bilateral trade in buffering compounding climatic and non-climatic shocks to global grain supplies. The topic is timely, policy-relevant, and well aligned with current debates on food system resilience. The modelling framework is sophisticated and the dataset is extensive. However, despite its strong scientific contribution, the manuscript would benefit from substantial revisions in academic writing quality, stylistic consistency, clarity of exposition.

The comments. Thank you for the opportunity to review this manuscript, titled "Limits to trade's buffering of compounding climatic and non-climatic shocks to global grain supplies." The paper presents a sophisticated and highly relevant analysis using a novel bilateral trade model to assess global food system resilience. The topic is timely, the methodology is robust, and the findings are significant for both policy and research.

-The manuscript presents a comprehensive and methodologically robust analysis of the role of bilateral trade in buffering compounding climatic and non-climatic shocks to global grain supplies. The topic is timely, policy-relevant, and well aligned with current debates on food system resilience. The modelling framework is sophisticated and the dataset is extensive. However, despite its strong scientific contribution, the manuscript would benefit from substantial revisions in academic writing quality, stylistic consistency, clarity of exposition, and formal presentation, as detailed below.

Thank you very much for your kind words. We are glad to see that our work's importance is recognised by the reviewer.

-The title is clear and descriptive. Consider if "Limits to trade's buffering..." could be slightly rephrased for immediacy, e.g., "The Limits of Trade in Buffering Compound Shocks to Global Grain Supplies."

We have changed the title in line with the suggestion below.

-Title: The title should be precise, clear, and reflective of the research content. Consider revising the title to be more specific, such as: "Assessing the Resilience of Global Grain Supplies to Compound Climatic and Non-Climatic Shocks through a Bilateral Trade Model".

We have changed the title to: "Assessing the Resilience of Global Grain Supplies to Compound Climatic and Non-Climatic Shocks".

-Abstract: The abstract should be concise and clear, summarizing the research objectives, methodology, key findings, and conclusions. Review the abstract to ensure no redundant or excessive information is included.

-Abstract: The final sentence ("The modelling approach developed here can be a useful tool...") is somewhat generic. Strengthen it by briefly stating what kind of strategies it can help identify (e.g., "...identify targeted strategies for enhancing resilience, such as strategic stockholding or trade agreement diversification").

We have now added this.

-Abstract: "Recent extreme-weather events and international conflict have heightened concerns about the vulnerability of the global food system to shocks." Could be rephrased to: "Recent extreme weather events and international conflicts have raised concerns about the global food system's vulnerability to shocks."

We have changed this, thanks for the suggestion.

-The introduction should provide a clear background on the research topic, its significance, the gap in previous research, and the objectives of the current study. Review the introduction to ensure it clearly defines the research contribution to the field.

-Paragraph 1: "providing food and feedstock for a growing population [1]" → Consider "providing food and feed for a growing global population [1]" for parallel structure.

We have changed this.

-Paragraph 2: "There is evidence that the frequency...has increased" → "Evidence suggests that the frequency...has increased" is more standard academic phrasing.

We have changed this.

-Paragraph 3: "A low level of resilience can cause..." → "Low resilience can lead to..." is more concise.

We have changed this.

-In the Introduction: "At present, around 20% of all calories consumed globally are from traded food products [2]." Consider adding more explanation or recent statistics if available to strengthen the sentence.

We have added an additional statement about the increase in global food trade in L36-37.

-Page 2, Intro: "have doubled the number of people facing acute food insecurity" → This refers to a past event (2019-2023), so "had doubled" is more precise.

We have changed this.

Materials and Methods:

-Section 2.1: "our 'present- day' reference period" → Use a consistent format for defined terms. Consider "our 'present-day' reference period (2017–2021)" on first mention.

We have used the term "reference period" instead of "present-day" throughout now, as we believe this is a better phrase.

-Section 2.2: "The benefits of a SPEM are, first, that it explicitly captures..." → Use a stronger list format: "The benefits of a SPEM are fourfold. First, it explicitly captures... Second, it allows for... Third, it captures... Fourth, it allows..."

We have changed this.

-Section 2.3: "We consider four shock scenarios that are super-imposed upon..." → "superimposed on" is the standard form (no hyphen).

We have changed this.

-Throughout: Avoid phrases like "we do" or "we use" where possible. Focus on what was done. E.g., "The model was calibrated using..." instead of "We calibrated our model using..."

Thank you for this suggestion. We indeed identified a mixed tenses throughout, which we have now made consistent. The methodology is now written in past tense when talking about the steps taken to set up our model.

-Several passages, particularly in the Introduction and Discussion, employ narrative or journalistic phrasing (e.g., "heightened concerns", "grounds for optimism"). These should be revised to a more neutral, analytical, and cautious academic tone. Subjective or evaluative language should be minimized unless clearly supported by evidence.

We have changed this throughout.

-Key concepts such as compound shocks, systemic shocks, and interconnected shocks are used interchangeably without a clear, unified definition. The manuscript would benefit from: A formal definition of each key concept at first use. Consistent terminology across all sections.

We have now introduced and defined these key concepts in our methodology section. We removed any reference to systemic shocks and interconnected shocks for clarity.

-The manuscript contains a high frequency of overly long and syntactically complex sentences, especially in the Introduction and Methods sections. Many sentences combine multiple ideas (background, method, result, implication) and should be split for clarity. Simplifying sentence structure would substantially improve readability and accessibility.

We have carefully reviewed the manuscript and made edits throughout.

-There is inconsistent use of verb tenses across sections: Methods sometimes shift between past and present tense (Methods in the past tense, results in the present tense, conclusions in the Present tense).

With respect we prefer to have this tense structure. Methods refer to tasks performed in the past while the results and conclusions are more naturally in the present tense. We have checked that this structure is used consistently.

-Figure captions (e.g., Figure 1. Risk profile...) are embedded directly within the text body. In the final manuscript, figures and tables should be inserted in their appropriate locations or placed at the end of the document. The text should refer to them (e.g., As shown in Figure 1...) rather than pasting the caption as a standalone paragraph. References to supplementary tables like Table S1 are acceptable, but ensure these files are actually included as appendices.

We have checked all figures and their text.

-While passive voice is acceptable in scientific writing, its excessive use, particularly in the Methods section, reduces clarity and authorial responsibility. The authors should consider introducing active constructions where appropriate to improve transparency and flow.

We have used passive voice in the methods to refer to activities to set up our model and active voice in the other parts of the manuscript.

-Some analytical choices (e.g., use of Spearman rank correlation) are reported without sufficient methodological justification. Brief explanations should be added to clarify why each statistical method is appropriate for the data structure.

We have added a sentence to highlight this, see L326-329.

-In some instances, trends described in the text are not immediately evident in the corresponding figures. The authors should carefully check consistency between narrative descriptions and visual representations.

We have checked this concern throughout and made changes where we have identified this issue.

-The Conclusion section largely reiterates results rather than clearly articulating the manuscript's original contributions.

We would like to keep this section in its current form: our conclusion section is very short, summarising the results and briefly exploring their implications.

-Line 16: "Recent extreme-weather events and international conflict have heightened...". Improvement: Consider making it more forceful: "The convergence of recent extreme-weather events and international conflicts has heightened..." to link the factors more tightly.

We have changed this.

-Line 369: "...increase in global consumer price (weighted by demand) of 22.6% for soybean..." Improvement: To enhance statistical rigor, it is advisable to report confidence intervals or standard deviations alongside the percentages/medians, especially when discussing median values over 54 samples.

Thank you for this suggestion, we have purposely not included confidence interval here as there is not a concise way of reporting on the confidence intervals of two distributions. However, Figure S8 shows how the distribution changes across the scenarios.

-The transition between "3.4 Shifting trade patterns" and "3.5 Country coping capacity" is generally good. However, you could add a linking sentence at the end of section 3.4 indicating that these trade shifts affect countries differently based on their coping capacities, setting up the next section.

We have removed section 3.4 now in line with Reviewer's 2 comment, so this comment is not needed anymore. In fact, we have now integrated the reference to trade shifts in Section 3.5 (which is now 3.4).

Results & Discussion:

-Section 3.1: "most of Europe and North Africa have low prices" → "exhibit low prices" or "are characterized by low prices."

We have changed this.

-Section 3.2: "Regionally, however, we can identify different drivers..." → "Regionally, however, the drivers of consumer surplus losses differ..." (More active, less tentative).

We have changed this.

-Section 4 (Discussion): The discussion is strong. Ensure each paragraph begins with a clear topic sentence that links back to the results or forward to the broader implication.

Thank you.

-General Flow: Transitions between some paragraphs, particularly in the Methods, can be improved. Use linking phrases: "To implement this," "Consequently," "Following this calibration," etc.

"impacts as a result of" → "impacts resulting from" is more formal.

"super- imposed upon" → "superimposed on."

"Exemplar shocks" → "Exemplary shocks" or, better, "shocks exemplified by..."

"Locate food systems vulnerabilities" → "identify vulnerabilities in food systems."

We have made the suggested changes.

-Ensure every figure and table mentioned in the text (e.g., Figure 1, Figure S1, Table S2) is explicitly called out in a logical place, preferably before the reader encounters the related data in the text. The current manuscript is generally good, but double-check the flow.

-Example for Figure 1 caption (Page 13): "Fig. 1 | Risk profile of consumer prices related to climate-driven yield variations. (a) Bivariate plot of the mean consumer price (averaged across the 54 yield years) and the coefficient of variation (COV) of consumer prices over the same period for all four crops combined (weighted average) under the baseline scenario. (b–e) As in (a), but for maize (b), wheat (c), rice (d), and soybean (e) separately. Darker red indicates high price variability but low consumer prices. Darker gold indicates low variability but high prices. Black indicates both are high."

We have checked this.

-The table on Page 34 appears to be raw data or a misplaced element. It should be formatted as a proper table with a caption (e.g., "Supplementary Table X: Correlation coefficients...") and moved to the Supplementary Information.

We are confused here as Page 34 does not exist and we cannot identify a table matching this description. Possibly this is a pdf glitch.

-Use consistent terms: "consumer surplus" (not "consumer's surplus"), "coping capacity," "systemic risk."

We have checked the consistent use of terms and introduced them accordingly in the methodology (Section 2.5 Impact metrics).

-Supplementary Information: The manuscript frequently refers to "Text S1," "Figure S1," etc. Ensure that all these supplementary items are prepared, clearly labeled, and submitted with the manuscript. Their descriptions in the main text should be precise enough for the reader to understand what is being referenced.

We have checked this.

-I commend the authors on their substantial work. Addressing the comments above will significantly enhance the manuscript's clarity, credibility, and suitability for publication.

Many thanks for these helpful and constructive comments.

Reviewer #2: This manuscript presents a global bilateral trade model for four major staple crops (maize, wheat, rice, soybean) across 177 countries to examine the extent to which international trade can buffer, or sometimes amplify, compounding climatic and non-climatic shocks to food supplies and prices. The topic is timely, important, and clearly within the scope of PLOS Climate. Overall, I find the work methodologically sound, policy-relevant, and suitable for publication after addressing a number of clarifications and extensions noted below.

Overall assessment and contribution

The paper makes a valuable contribution by bringing together:

-A global, bilateral, multi-commodity trade framework.

Multiple classes of shocks (climate-induced yield variability, conflict-related disruptions inspired by the Ukraine war, energy price shocks, and trade bans).

An explicit focus on compound shocks and their implications for consumer surplus, prices, and trade patterns.

The study shows that:

Non-climatic shocks, particularly energy price shocks, can dominate climate-related yield shocks in terms of global impacts on prices and welfare.

Trade adjustments often help buffer shocks but with clear limits and heterogeneity across countries and crops.

Under unfavorable global weather conditions combined with a compound shock, global losses in consumer surplus can exceed USD 600 billion and affect a large number of countries.

This is an important result, and the paper advances the discussion about food system resilience by explicitly quantifying how shocks of different types, and in combination, propagate through trade networks.

Thanks you very much for your kind words.

Methods and statistical / quantitative rigor

-The study is framed as a global partial-equilibrium trade model rather than a classical statistical analysis, which is appropriate for the questions addressed. Within that paradigm:

-The model structure (countries \times crops \times bilateral trade flows) and the representation of supply, demand, and trade are in line with current practice in the food and climate risk modeling literature.

Parameter choices (elasticity, baseline trade and production, etc.) appear to come from recognized data sources and the existing literature.

The shock formulations (climatic yield variability, conflict-related shocks, energy price shocks, trade bans, and their compound combination) are plausible, scenario-based constructions.

-On balance, I consider the analysis to be:

Appropriate for the research question.

Implemented with a reasonable level of rigor.

Transparent enough (given the text) that another group could conceptually replicate or extend it, especially if code and processed data are made available as indicated.

That said, there are several areas where additional explanation or robustness analysis would considerably strengthen the paper.

Thanks you very much for your kind words. Below, you can find the changes we have made to improve the robustness of the paper.

Major comments

1. Clarify model structure and key elasticity

The description of the trade model is central to the paper's credibility, and it would help to provide a slightly more explicit, self-contained treatment. In particular:

Please clarify:

The exact functional forms used for supply, demand, and trade (e.g., Armington, CES, log-linear, etc.), and how price pass-through is modeled.

The sources and ranges for key elasticity (demand, supply, trade substitution), and whether they vary by country and crop.

How domestic consumption is linked to world prices versus local prices, and how any trade or transaction costs are treated.

I recommend adding either a schematic or a concise mathematical formulation in the main text, and moving fuller derivations and parameter tables to the Supplementary Information if space is a concern. This will help readers assess the strength of your conclusions about buffering limits.

Thank you for raising this important comment. We initially provided parts of the detailed methods in the main text, but felt that it would be better to have all mathematical details in the supplement together, as there is quite a lot, covering six pages. Now we have the detailed

model formulation in S1, the validation in S2, a visualisation of the input data in Figures S1-S5, the trade data visualised in Figure S24, and an overview of all model data in Table S1. We believe having this detailed information in the Supplementary Information helps for clarity, as the main manuscript is already extensive (10,000 words, including references). We have added a sentence to the MS explicitly saying that the information the referee refers to is in the SI which we hope addresses this concern, see L220-224.

2. Treatment of uncertainty and robustness

The paper currently relies on a set of well-motivated scenarios but would benefit from a clearer treatment of uncertainty:

It would be helpful to:

Perform and report at least a simple sensitivity analysis on key elasticity and key shock magnitudes (e.g., how do results change under high vs low price elasticity, or under somewhat weaker/stronger energy price shocks?).

Clarify whether the climatic yield variability shocks are derived from a probabilistic distribution (e.g., historical inter-annual variability, climate model ensembles) and how many realizations are used, or whether these are stylized scenarios.

If computational constraints prevent extensive sensitivity analysis, a smaller number of carefully chosen variants with clear plotting of differences (e.g., changes in global consumer surplus, number of countries with severe supply losses) would substantially increase confidence in the robustness of the conclusions.

An overview of the climate-yield variability shocks is provided in L236-248. In essence it can be considered a probabilistic distribution of present-day yield deviations based on historical weather patterns. We have clarified this further in the text.

Unfortunately, due to computational constraints, as the reviewer already indicated, it is prohibitively expensive to do a comprehensive sensitivity analysis. This is because we already have a 54 year stochastic baseline. To test multiple shock severities, one has to run multiple 54 year stochastic realisations to meaningfully compare the impacts. The same holds for other important parameters, such as the demand elasticity. We recognise that this is a clear limitation, but is a worthwhile sacrifice to achieve the benefits of having a stochastic model. In other words, our efforts to advance previous work by looking more explicitly at weather-driven stochastic yields across the globe comes at the expense of not being able to do a comprehensive sensitivity analysis. We have stated this more explicitly in the limitations section, see L610-619:

“Fourth, the probabilistic set-up of our modelling framework, involving 54 years of weather-driven yield fluctuations, makes it computationally difficult to systematically explore variations in other model parameters. For instance, the analysis of coping capacities, indicated the demand elasticity to be an important parameter shaping a country’s food system resilience, but we have not been able to do a full sensitivity analysis.

Fifth, the specificity of the compound shock modelled in this study limits us from making statements about the generalizability of our findings beyond the context of these shocks. Future work could consider relaxing some of the model’s granularity (e.g., number of countries) and test a larger subset of shock scenario’s.”

3. Distinguishing model “shock stories” from empirical events

The manuscript uses exemplar shocks motivated by the Ukraine war, energy price spikes, and observed trade bans. This is a powerful way to make the results policy-relevant, but it is important that readers clearly understand:

Which aspects are stylized, scenario-based abstractions versus empirical reconstructions. To what extent the “Ukraine-like” or “energy price-like” shocks match observed magnitudes and patterns, and where you intentionally deviate for stress-testing purposes. I suggest being explicit in the text and/or a table about:

The calibration of each shock (e.g., percentage reduction in exports from a specific region, energy cost pass-through to production costs, scale of trade bans).

Whether each scenario is intended as a plausible historical analogue, an upper-bound stress test, or something in between.

This will prevent readers from over-interpreting the scenarios as exact reproductions of recent events.

Thank you for this valuable comment. We indeed use the Ukraine war, energy price spike and trade bans as the motivation for our shock scenarios, which was also chosen because detailed data (trade bans) is available. However, we do not want to frame this paper as an empirical reconstruction of this shock, because in reality other disruptive phenomena and interactions occurred at the initiation of the war in Ukraine, which interacted in more complex ways with the food system than modelled here. Moreover, we are using plausible scenarios of climate-driven yield deviations, rather than an empirical reconstruction of yields. We have now further clarified what we intended to do with our shock scenario set-up and how the results should be interpreted:

Introduction (L126-131), Method (L228-L234) and Limitations (L616-619).

4. Interpretation of trade’s “buffering” vs “amplifying” role

One of the key conceptual contributions is the assessment of trade as a buffer or amplifier. To make this more transparent:

Please clarify:

How you define and measure “buffering” and “amplifying” outcomes in quantitative terms (e.g., comparison to an autarky baseline, or to a scenario with restricted trade flows).

Whether buffering is evaluated globally, regionally, and/or for specific vulnerable country groups, and over what time horizon (single-year shock vs multi-year sequences if relevant). It could be particularly illuminating to show:

A comparison between the actual trade network and a counterfactual with more restricted

trade, for at least one or two key scenarios, to highlight when and where openness helps or hurts.

Simple metrics (for example, changes in variance of consumption or prices across countries) with and without trade adjustment.

These additions would make the “limits to buffering” conceptually sharper.

We agree that the exact definition of buffering/amplifying is not clear. We have therefore removed it from the title and removed reference to buffering/amplifying.

What we mainly test is whether the reliance on trade increases or decreases the modelled consumed surplus impacts as a result of shock scenario's, with a positive relationship indicating an amplifying effect whether a negative relationship the opposite.

5. Country-level heterogeneity and equity implications

The paper emphasizes variation in impacts across regions and countries, which is crucial from a food security standpoint. I encourage you to:

More explicitly identify which types of countries are most exposed (e.g., net food-importing low-income countries, conflict-affected states, high-import-dependence small economies) and why, in terms of the model structure.

Where possible, relate these groups to existing vulnerability classifications (e.g., LIFDCs, SIDS, etc.), even if just qualitatively.

Some additional maps or summary plots that highlight:

Top decile of countries by loss in calories or consumer surplus.

Shifts in trade dependence for these countries under different shocks.

would make the equity and justice implications of the findings more tangible.

Thank you for these useful comments. While we look at the relationship between consumer surplus and some country characteristics, we do not classify/group countries accordingly. We have now tested whether SIDS/non-SIDS are more affected by the systemic impacts, as well as three groups of countries according to their income classification (low, middle, high). See L454-464 for a discussion of these results.

We are also careful about over-emphasising the narrative on equity/justice, as there are often complicating social and political factors that shape whether certain countries can actually access food during crisis (e.g., negotiation power).

Data availability and reproducibility

The Data Availability Statement indicates that the underlying data used to build the baseline (e.g., FAO/other public databases) and the model outputs will be fully available, consistent with PLOS policy. This is essential for a modeling paper of this kind.

To strengthen reproducibility further, I recommend:

Depositing the core model code (or at least a reduced, documented version that reproduces key figures and tables) in a public repository with a DOI.

Providing a short “how-to-reproduce” section (e.g., which scripts to run and in what order to

regenerate main results) in the Supplementary Information or repository README. This will greatly enhance the utility of your work to other researchers and to policy analysts.

We have made all data (to run the model) and code availability, see reference 68 provided in the manuscript.

Presentation and clarity

The manuscript is generally well written and logically structured, but a few improvements could help:

Consider tightening some sections of the Results by focusing more on a small number of “headline” findings and using figures or tables to summarize finer detail.

Ensure that all acronyms are defined on first use, especially for readers coming from climate science or policy backgrounds rather than trade economics.

Where you report large aggregate monetary figures (e.g., USD 600 billion), briefly remind the reader what these represent (consumer surplus loss in a given year, under which compound shock configuration) and, if possible, provide context (e.g., relative to global agricultural GDP).

These changes would make the paper more accessible to an interdisciplinary readership.

Thank you for these suggestions. We have now edited the text further with this in mind, also incorporating some of the editorial suggestions of the other reviewer.

More specifically, we have removed Result Section 3.4 as we believe it was too descriptive, rather than part of our key headline findings. We have also put the systemic impacts into perspective by also expressing them as relative reduction in consumer surplus, see L433-445.

Ethics and dual publication

I did not identify any concerns regarding research ethics, dual publication, or publication ethics based on the manuscript text. The work is based on secondary data and modeling, and there is no apparent human-subjects or animal-related component.

In summary, this is a strong and timely manuscript that addresses an important question at the intersection of climate risk, trade, and food security. The modeling approach is appropriate and, as described, technically sound. The main conclusions about the limits of trade’s buffering role under compounding climatic and non-climatic shocks are well motivated and of high policy relevance.

I recommend publication after the authors:

Provide clearer detail on model structure and parameterization.

Add or better document sensitivity/uncertainty analysis.

Clarify the status of exemplar shocks as stylized scenarios.

Sharpen the definitions and metrics of trade “buffering” vs “amplifying.”

Strengthen the discussion of heterogeneous and equity-relevant impacts.

These revisions will significantly enhance the clarity, robustness, and impact of the study.

Many thanks.