# The contribution of international food trade to dietary risks and mortality at global, regional, and national levels

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**Article**

**Keywords:**

**Posted Date:** September 14th, 2022

**DOI:** https://doi.org/10.21203/rs.3.rs-1582276/v1



**Version of Record:** A version of this preprint was published at Nature Food on October 9th, 2023. See the published version at https://doi.org/10.1038/s43016-023-00852-4.

# Abstract

About a quarter of all food produced for human consumption is internationally traded, including foods with important public health implications such as fruits, vegetables, legumes, nuts, and red meat. Food trade is generally perceived to increase the availability and diversity of foods available to consumers, but there is little empirical evidence on its implications for human health. Here we show that food trade has a substantial impact on dietary risks and mortality worldwide, and that whether impacts are positive or negative depends on the types of foods traded. Using bilateral trade data for 2019, together with food-specific risk-disease relationships, we estimate that international trade in fruits, vegetables, legumes, and nuts improved dietary risks in the importing countries and was associated with a reduction in mortality from non-communicable diseases of ~ 1.4 million deaths globally. In contrast, trade in red meat aggravated dietary risks in the importing countries and was associated with an increase of ~ 150,000 deaths. We identified European countries as the greatest importers of health-promoting foods, and countries in the Americas as the greatest exporters, whilst Germany, the USA, Spain, Brazil, and Australia were leading exporters of foods that increase dietary risks. The magnitude of our findings suggests that safeguarding the trade in health-promoting foods from disruptions, whilst limiting those of unhealthy ones can make substantial contribution to maintaining and improving population health. We anticipate that considering impacts on dietary risks will become important aspects for health-sensitive trade and agriculture policies, and for policy responses to disruptions in food chains.

# Introduction

About a quarter of all food produced for human consumption is internationally traded[1]. Trading food between countries is generally perceived to increase the supply, access, and diversity of food available to consumers[2–4], and in principle can contribute to greater food and nutrition security[5–9], and a more efficient use of environmental resource[10]. However, concerns have been raised about the role food trade plays in outsourcing environmental pollution[11–14], and the health risks associated with changing dietary patterns and increasing levels of overweight and obesity[15–18]. Despite the ongoing discussion, the empirical evidence on the relationship between the trade in food and health outcomes remains scarce[19,20].

Here we quantify the impact of international food trade on dietary risk factors and mortality. Dietary risks include eating too few fruits, vegetables, legumes, and nuts, and too much red meat (including beef, lamb, goat, and pork)[21–23]. They are a leading cause for non-communicable diseases (NCDs) such as heart disease, stroke, cancer, and diabetes, and collectively responsible for one in five deaths globally[22,24,25]. Linking dietary risks to international food trade can help identify the role food imports play for dietary health in the importing country and trace the responsibility for those impacts to the exporting country. We use this demand-driven perspective to derive implications for health-sensitive food, trade, and agriculture policies. Such policies have particular relevance in light of possible trade disruptions from domestic policies such as Brexit, natural disasters such as from climate change, and armed conflicts such as between Russia and Ukraine.

For our analysis, we used detailed bi-lateral trade data [1] and an algorithm that links food consumption with primary production [26] to track the contribution food exports of one country made to national consumption in another country, and we used established risk-disease relationships [27–32] together with mortality rates and population numbers [33] to estimate the impact traded foods had on diet-related diseases and mortality (please see the Methods section for further details). As contribution of trade we understand the difference between consumption that includes imported foods versus a level of consumption that does not include imported foods. This demand-driven perspective allowed us to identify trade-related dependencies of dietary risks. Our analysis complements and differs from economic analyses of trade scenarios that take into account economic feedbacks across regions and markets.

# Results

According to our analysis, more than 190 million tonnes (Mt) of foods related to dietary risks, representing 3–12% of their production, were exported from one country to another in the year 2019 (SI Table 6, SI Fig. 1). Those included 86 Mt (11% of production) of fruits, 58 Mt (5%) of vegetables, 25 Mt (11%) of red meat, 12 Mt (3%) of legumes, and 8 Mt (12%) of nuts. Most fruits, legumes, and nuts were exported from the Americas (42 Mt, 27%; 8 Mt, 3%; 4 Mt, 48%), especially Brazil and Argentina; most vegetables from Asia (22 Mt, 2%), especially China; and most red meat from Europe (12 Mt, 25%), especially Germany.

Food imports increased the availability of these foods in the importing countries when compared to a situation without imports by an average of 3–31 grams per person per day (g/d), representing 5–21% of demand (SI Table 7, SI Fig. 1). Average food availability per person increased by 31 g/d for fruits (14% of demand), 21 g/d for vegetables (5%), 9 g/d for red meat (11%), 4 g/d for legumes (19%), and 3 g/d for nuts (21%). By region, the increases in food availability per person ranged from 4 g/d (2%) of fruits in Africa to 145 g/d (64%) in Europe, 7 g/d (4%) of vegetables to 94 g/d (32%) in Europe, 2 g/d (29%) of legumes in Oceania to 8 g/d (100%) in Europe, 1 g/d (5%) of nuts in Africa to 12 g/d (97%) in Europe, and 1 g/d (4%) of red meat in Africa to 34 g/d (23%) in Europe.

The related changes in food intake were associated with a net reduction in diet-related mortality of 1.2 million deaths (95% confidence interval, 0.8–1.7 million) (Fig. 1). About half of the avoided deaths (53%) were from coronary heart disease, and a quarter each from stroke (25%) and cancer (23%). The trade-related increases in fruit intake were responsible for the largest reductions in mortality (-597,000), followed by vegetables (-380,000), nuts (-300,000), and legumes (-98,000). In contrast, the trade-related increases in red meat intake were associated with an increase in diet-related mortality (+ 147,000).

Of the total reductions in diet-related mortality, more than half were associated with food imports to Europe (-675,000; 55%), especially fruits exported from the Americas and vegetables from other parts of

Europe (Fig. 2, SI Table 8). This was followed by imports to Asia (-301,000; 25%) and the Americas (-209,000; 17%), in each case driven by fruits and vegetables exported from within the region. Smaller proportions were associated with imports to Africa (-33,000; 3%) and Oceania (-7,000; 1%), including vegetables from Asia and Europe. When attributing health impacts to the exporting region, the Americas were the largest contributor to diet-related reductions in mortality (-507,000; 41%), followed by Asia (-365,000; 30%), Europe (-231,000; 19%), Africa (-118,000; 10%), and Oceania (-5,000; 0.4%).

At the country-level, imports of health-sensitive foods (i.e., foods related to dietary risks) contributed to health benefits in 152 out of 153 importing countries (Fig. 3, SI Fig. 2). The countries with the greatest health benefits, driven to large degrees by imports of fruits and vegetables, were the USA (-140,000), Russia (-134,000), Germany (-107,000), China (-89,000), and the UK (-61,000). The same set of countries also benefitted from imports of nuts and legumes, and other leading beneficiaries included Italy and India for both nuts and legumes, and Bangladesh and Egypt for legumes (Fig. 4). The only country exhibiting a net increase in diet-related mortality from trade was Papua New Guinea (+ 4 deaths) where the negative health impacts associated imports of red meat exceeded the positive impacts of food imports.

Out of 181 countries that exported health-sensitive foods, 162 (90%) contributed to reductions in diet-related mortality through their exports, and 19 (10%) to increases (Fig. 3, SI Fig. 2). The countries whose exports contributed most to a reduction in diet-related mortality were China (-117,000) driven by vegetables and nuts, the USA (-102,000) driven by nuts and legumes, Brazil (-92,000) and Spain (-86,000) both driven by vegetables and fruits, and Turkey (-69,000) driven by fruits. Other leading exporters were Ecuador and Mexico for fruits; Italy and the Netherlands for vegetables; Argentina and India for nuts; and Canada for legumes (Fig. 4). The countries that contributed to net increases in mortality through high exports of red meat included Germany (+ 10,000), Denmark (+ 7,000), Ireland (+ 3,500), Uruguay (+ 2,000), and Paraguay (+ 1,400).

# Discussion

We quantified the contribution of international food trade to five dietary risks and associated mortality. We found that international trade in fruits, vegetables, legumes, and nuts improved dietary risks in the importing countries and was associated with a reduction in mortality from non-communicable diseases of 1.4 million deaths globally. In contrast, trade in red meat aggravated dietary risks in the importing countries and was associated with an increase of 147,000 deaths. The net change in mortality attributable to food trade amounts to a fifth (19%) of the total diet-related health burden that is associated with eating too few fruits, vegetables, legumes, nuts, and too much red meat[34]. Thus, our analysis implies that food trade has substantial impacts on dietary risks worldwide.

Our study has several strengths that advance the current literature on health and trade. First, it links food trade to final health outcomes instead of considering markers of dietary health[20]. Second, it explicitly resolves trade patterns instead of considering indices of trade openness[19]. Third, it provides country-level analyses for all countries participating in international trade instead of focusing on specific regions.

Fourth, our method of linking food trade to dietary risks and associated mortality is less time and context-dependent than existing regression analyses [35], and can be flexibly applied in future research, including in longitudinal studies of trade, and analyses of past and future trade agreements[36].

Our study is also subject to several caveats. First, our analysis covered major dietary risks, but it did not analyse the impacts food trade can have on other aspects important for health. Those include the impact food trade has for overweight and obesity in the importing countries[15–17], or the relationship between food trade and consumption of ultra-processed foods[37,38]. Process-based analyses of these and further health aspects related to trade are an important avenue for future research[19,20]. As such, our study cannot determine whether food trade is generally beneficial or detrimental for health.

Second, our study is subject to caveats that apply to comparative risk assessments and nutritional epidemiology[39]. In particular, our health analysis is based on the assumption that the risk-disease relationships we used to link changes in dietary risks to mortality describe causal associations. This assumption is supported by the existence of statistically significant dose-response relationships in meta-analyses, the existence of plausible biological pathways, and supporting evidence from experiments, e.g. on intermediate risk factors[27–32]. However, residual confounding with unaccounted risk factors cannot be ruled out entirely in epidemiological studies.

Our study adds to the body of evidence suggesting that food trade can play both positive and negative roles for health. Past analyses have quantified trade's positive impact on nutritional adequacy, especially in high and middle-income countries[8], but also its role in increasing obesity, especially in low and middle-income countries[18]. Our findings suggests that when it comes to foods related to dietary risks, trade plays a largely positive role, especially for regions with substantial imports such as Europe, the Americas, and Asia. However, exceptions also exist, especially when focusing on the negative health impacts associated with exports of red meat, most of which originating from European and Latin American countries.

Our findings have several implications relevant for food, trade, and agricultural policy. The data on trade in dietary risks can help plan trade agreements and understand trade exposure. For example, we found that Europe was the largest net beneficiary of trade in dietary risks, whereas the Americas were the largest net contributor, and also Africa exported more dietary risks than it imported – in its case three times more (SI Table 6). Our analysis suggests that disruptions in the trade of foods associated with dietary risks can substantially affect the burden of diet-related diseases, especially in heavily import-dependent countries. Such disruptions can be the result of natural disasters related e.g. to climate change[40], nationalistic policies such as the UK's exit from the European Union[36], or armed conflicts.

A particularly recent example of disruptions in food trade is the Russian invasion of Ukraine in 2022. Both Ukraine and Russia are major exporters of grains, and a shortfall in their exports could impact global wheat prices and food security[41]. Our analysis indicates that the health implications of changes in their trade of foods related to dietary risks can be important too (Fig. 5). We found that Ukrainian exports contribute to a net reduction in mortality in importing countries of 12,600 deaths (most of which associated with nuts, legumes, and vegetables), which is at risk due to the Russian invasion. Russia, on the other hand, is one of the main beneficiaries of importing health-promoting foods – associated with 134,000 less deaths (most of which associated with fruits, vegetables, and nuts) – and therefore risks harming the health of their population should international sanctions include agricultural exports. Mitigating the impacts on trade in such foods could alleviate some of the indirect health consequences that this conflict could otherwise have.

Appropriate trade and agricultural policies can contribute to safeguarding the health benefits of trade, whilst minimising its harm. Reducing tariffs on the export and import of health-promoting foods such as fruits, vegetables, legumes, and nuts can ensure populations have access to a variety of foods critical to good health[36]. At the same time, the detrimental health impacts from the export of foods linked to increases in mortality could be reduced by increased tariffs and appropriate agricultural policies in the exporting country. In countries we identified as net exporters of foods linked to increased mortality such as Germany and Denmark, agricultural policies would be warranted that, instead of the current specialisation on livestock production for export, incentivise a transition towards greater diversification of production. As food trade is an important contributor to changes in dietary risks and mortality, safeguarding the trade in health-promoting foods, whilst limiting those of unhealthy ones will be important aspects of trade and agricultural policies.

# Methods

For tracking food trade between countries, we made use of detailed bilateral trade data provided by the Food and Agriculture Organization of the United Nations (FAO)[1]. The FAO collects and processes the data according to the standard International Merchandise Trade Statistics (IMTS) Methodology. It is based on source data provided by the United Nations Statistics Division (UNSD), Eurostat, and other national authorities. The FAO has checked the source data for outliers, added data on food aid, and build statistical models to derive estimates for non-reporting countries and to fill data gaps. The trade database includes all food and agricultural products imported and exported annually by country.

In the bilateral trade data provided by the FAO, the source country is usually the country where the last value-added production step has taken place. For example, when a country imports raw material, processes it and re-exports the product, it will be listed as the source country. We used a balancing algorithm based on input-output accounting to clearly link final demand to the origin of the primary product[26,42]. The algorithm is based on production data of primary products, bilateral trade data for primary products and the secondary products derived from those (e.g. oils), and conversion factors for converting secondary products into primary equivalents based on caloric content and using extraction rates (SI Tables 1–2).

We aggregate the commodity level detail to food groups relevant for health analyses, including to fruits, vegetables, legumes, nuts, and red meat (SI Table 3). We focused on those food groups for which disease associations have been identified in meta-analyses of epidemiological cohort studies[27–32], but note that other types of traded foods (e.g. ultra-processed foods) can also have implications for health (e.g. through their effect on weight levels). For analysing the health implications of traded foods, we converted the traded quantities into an equivalent change in per-capita consumption by dividing by population numbers and subtracting the proportion of food waste that occurs at the household level[43].

We developed a comparative risk assessment of dietary risks and used it to quantify the health implications of trade in food commodities. The comparative risk assessment included five dietary risks (fruits, vegetables, legumes, nuts, and red meat) and their relationship to five disease endpoints (coronary heart disease, stroke, colorectal cancer, and type 2 diabetes). The relative risk estimates that relate the risk factors to the disease endpoints were adopted from meta-analyses of prospective cohort studies (SI Table 4)[27–32], and mortality and population data by age group and country were adopted from the Global Burden of Disease project[33].

The selection of risk-disease associations used in the health analysis was supported by available criteria used to judge the certainty of evidence, such as the Bradford-Hill criteria used by the Nutrition and Chronic Diseases Expert Group (NutriCoDE)[21], the World-Cancer-Research-Fund criteria used by the Global Burden of Disease project[22], as well as NutriGrade (SI Table 5)[23]. The certainty of evidence supporting the associations of dietary risks and disease outcomes as used here were graded as moderate or high with NutriGrade[30–32], and/or assessed as probable or convincing by the Nutrition and Chronic Diseases Expert Group[21], and by the World Cancer Research Fund[44].

As our analysis was primarily focused on mortality from chronic diseases, we focused on adults aged 20 year or older, and we adjusted the relative-risk estimates for attenuation with age based on a pooled analysis of cohort studies focussed on metabolic risk factors[45], in line with other assessments[21,46]. In the uncertainty analysis, we used the low and high values of the 95% confidence intervals of the relative risk estimates and standard methods of error propagation to derive confidence intervals of our estimates of trade-related changes in mortality. Our reporting follows the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER; see SI reporting file)[47].

**Data Availability:** All data produced in this study are available as a Supplementary Data File available at https://docs.google.com/spreadsheets/d/10wfs1hK1Jn6yKr_GW4NQ3k9b

RYqwpdMD/edit?usp=sharing&ouid=115732602812472384954&rtpof=true&sd=true. All input data are available at https://docs.google.com/spreadsheets/d/1kHFpVbWzI8ChMR87L

Nyn67vwovgIkvmM/edit?usp=sharing&ouid=115732602812472384954&rtpof=true&sd=true. The files will be deposited in the Oxford University Research Archive (ORA) upon publication.

**Code availability:** The codes for the trade and health analyses are described in detail in the Supplementary Information and the references cited therein. They are available upon request.

# Declarations

**Acknowledgements:** MS acknowledges funding from Wellcome Trust (205212/Z/16/Z), HK acknowledges funding from Wellcome Trust (209734/Z/17/Z), and CD acknowledges funding from the Natural Environment Research Council Fellowship (NERC NE/N01524X/1) and contributions to Wellcome Trust (205200/Z/16/Z). We thank Thomas Kastner and are grateful to Christian Siderius for sharing the initial implementation of the trade-correction algorithm with us.

**Author contributions:** MS designed the study, conducted the analysis, interpreted the results, and wrote the manuscript. HK compiled the trade data, applied the trade-correction algorithm, and interpreted the results. All authors commented on the manuscript draft and approved the submission.

**Competing interests:** We declare no competing interests.

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# Figures

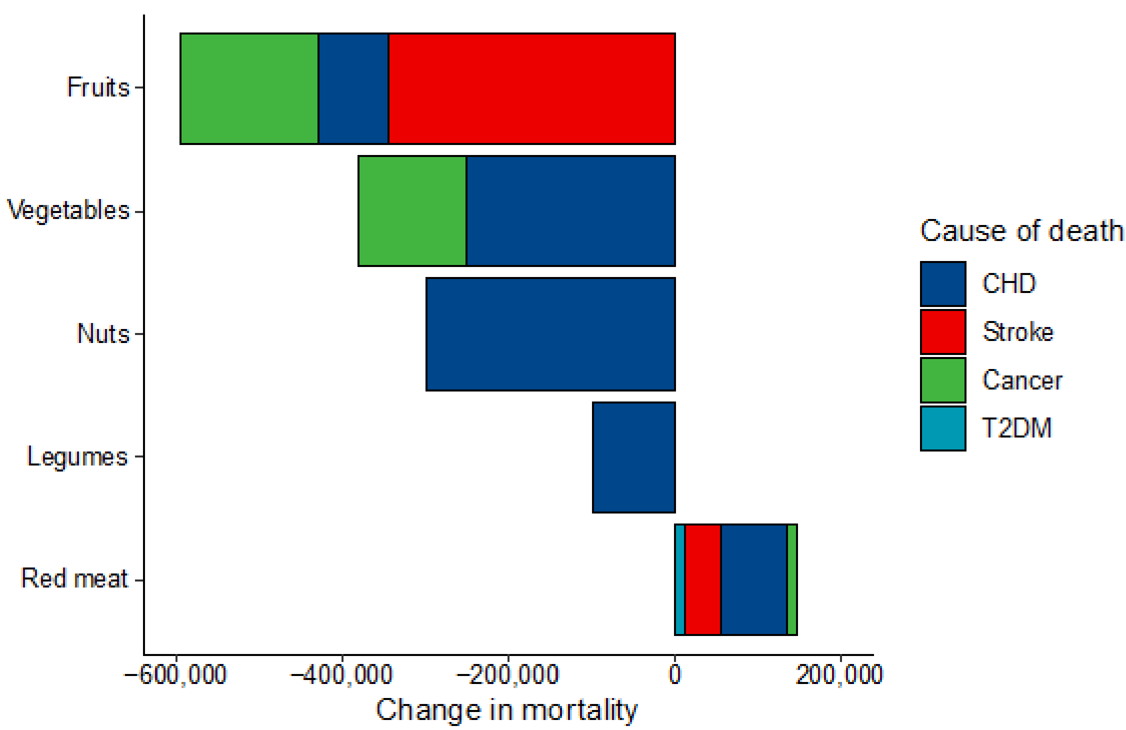
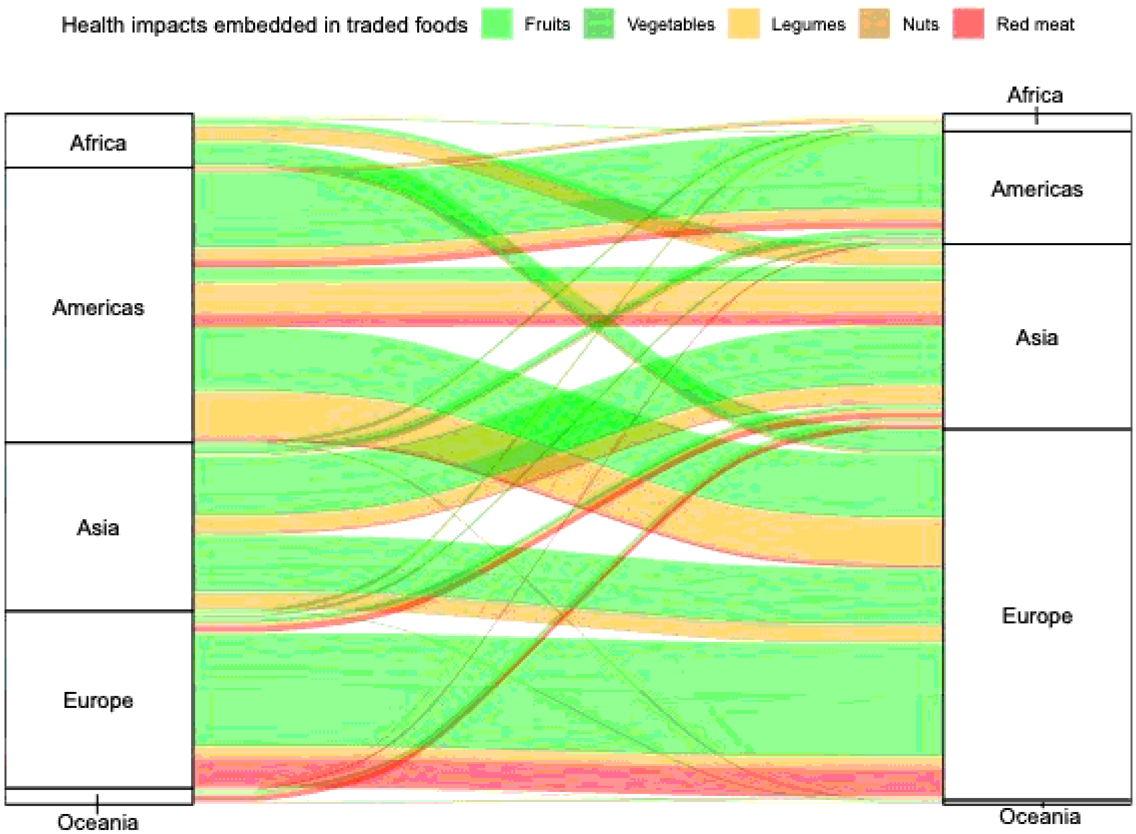



**Figure 1**

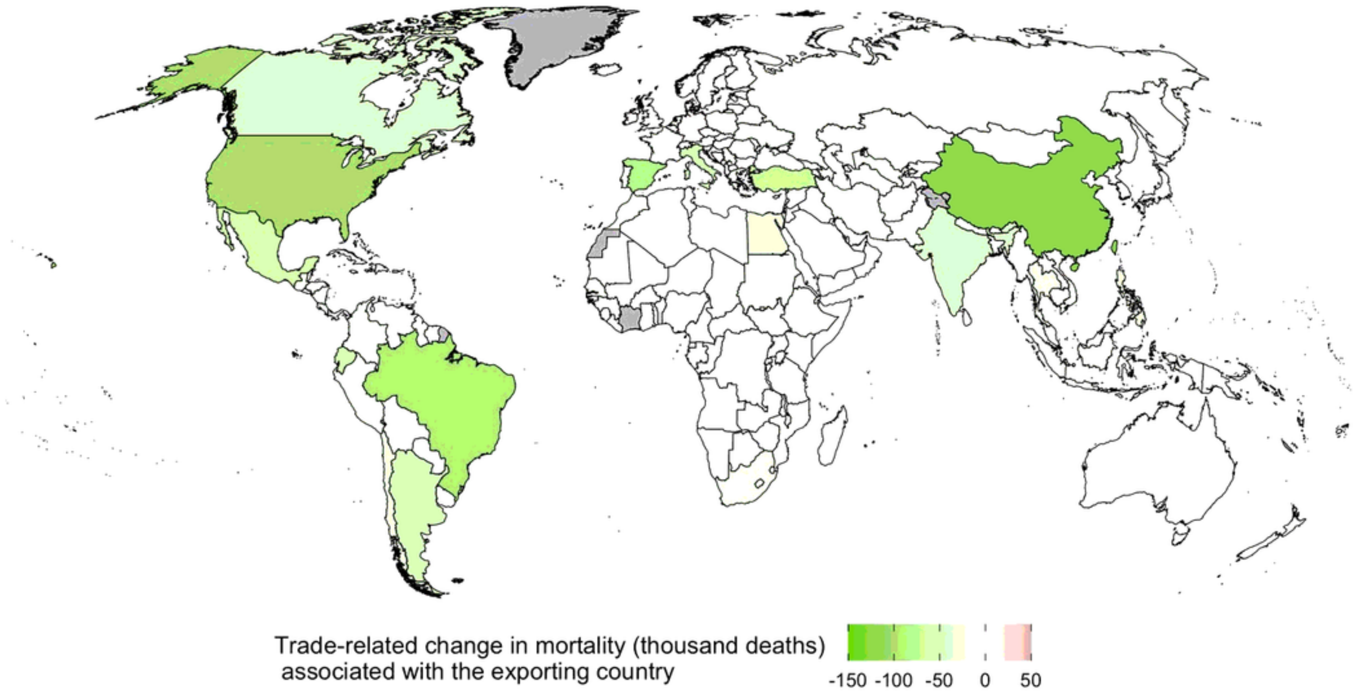
Contribution of traded foods to diet-related disease burden in the importing countries by dietary risk and disease.




## Figure 2

Trade flows of dietary risks, measured in changes in mortality, between exporting regions (left) and importing regions (right).

a




b

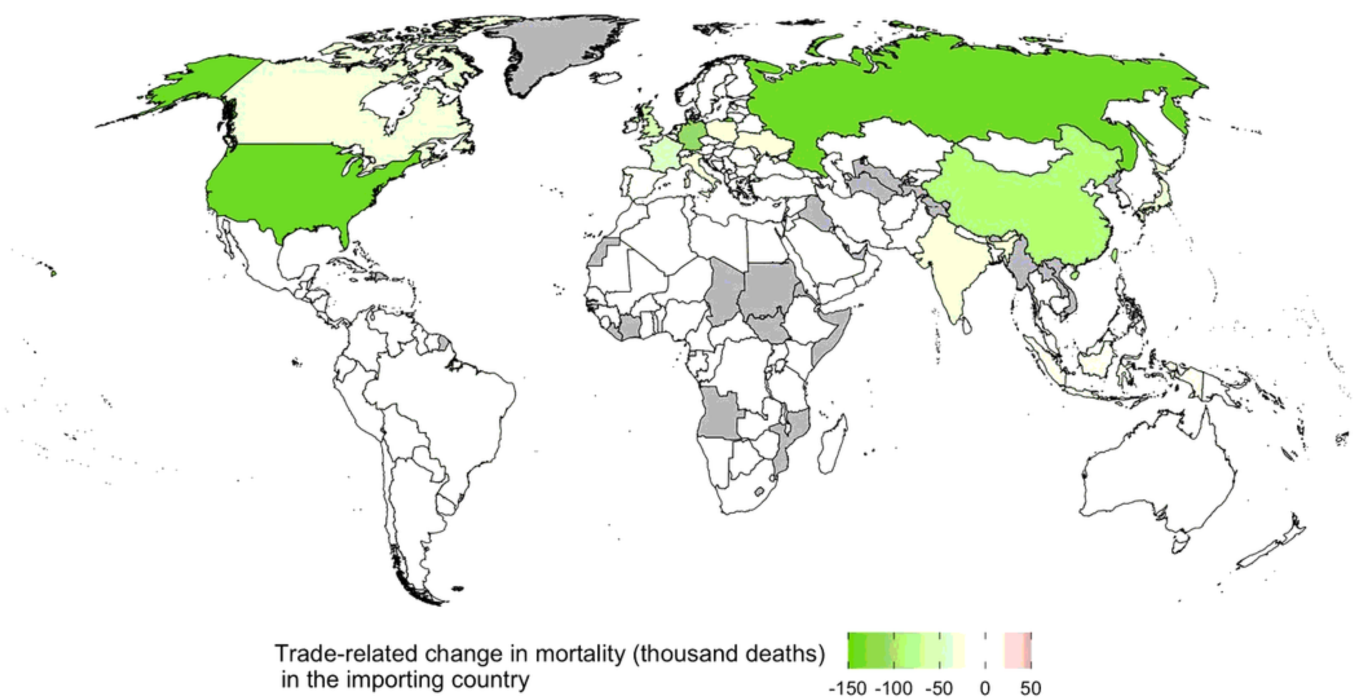
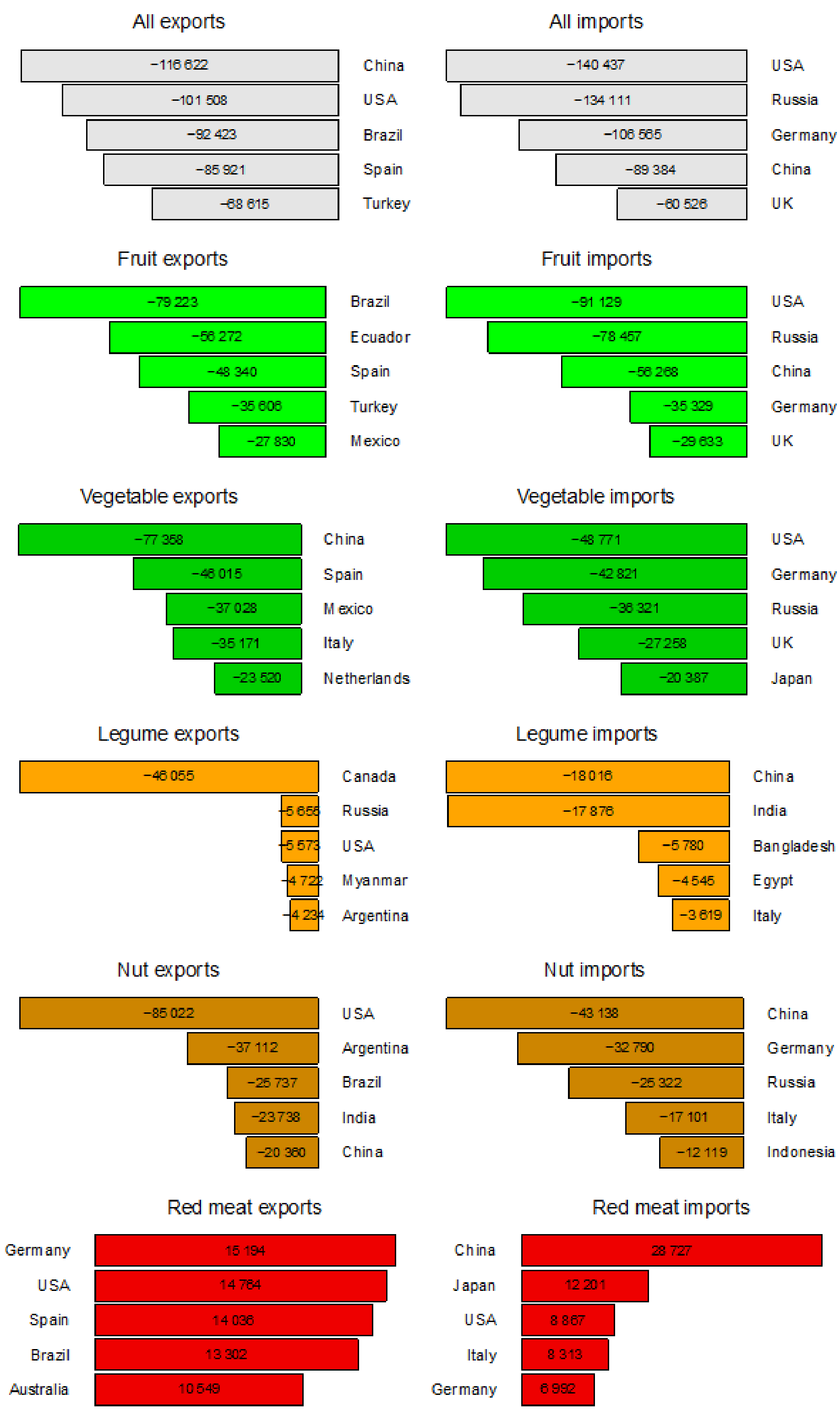


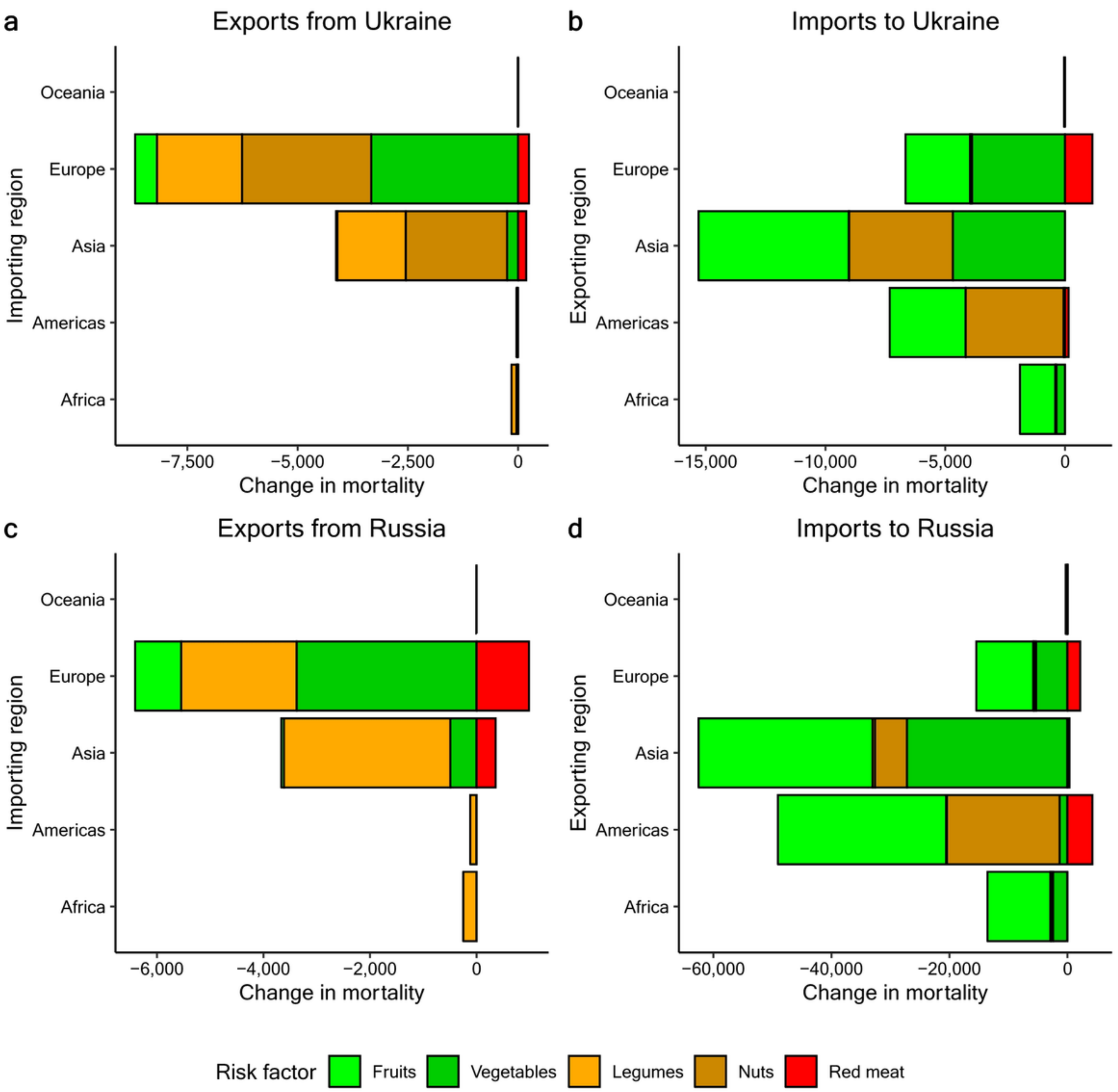

**Figure 3**

Exporters (a) and importers (b) of dietary risks, measured in changes in mortality.




## Figure 4

Leading importers and exporters of dietary risks by food group, measured in changes in mortality.




### Figure 5

Trade-related changed in mortality, measured in number of deaths, by risk factor and importing and exporting regions linked to Ukraine's food exports (a) and imports (b) and Russia's exports (c) and imports (d).

## Supplementary Files

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- GATHERchecklisttrade2health.docx
- tradeindietrisksSI090222NF.docx