Trading Responsibility: navigating national burdens in a globalized world

Navarre, N.H.

Chapter 1

General Introduction

1.1 International Trade

International trade has been touted as a key driver of global economic growth and globalization throughout much of the 20th and early 21st century (Song & Zhou, 2020). Trade has allowed nations to economically prosper by amplifying their ability to provide goods and services worldwide, raising the value of world merchandise exports from $59 billion in 1948 to $15,464 billion in 2016; 30% of global gross domestic product (GDP) (Wiedmann & Lenzen, 2018; WTO, 2018). This increase in trade value has helped high-income countries achieve unprecedented levels of affluence, spurring globalized consumer markets and advancing human development globally (Kónya & Ohashi, 2007). Low- and middle-income countries have also been able to economically leverage international trade, doubling real incomes, halving poverty rates, and consistently improving access to clean water and food (Wiedmann, 2016). However, some scholars and economists push back on the idea of international trade as an unequivocally positive source of economic and social benefits for countries worldwide, instead voicing concerns of growing inequality and a worsening of absolute poverty (Aradhyula et al., 2007).

Despite contentious economic and social outcomes, international trade has grown at a far greater rate than gross GDP or population since the 1970s, reaching unprecedented levels of scale and complexity (Wiedmann, 2016). The continued expansion of trade has led to more complex networks, with the production of single goods being fragmented across many different countries, while re-export hubs have become an essential service to harmonize these complex supply chains (Kónya &

Ohashi, 2007; Wiedmann, 2016; Wiedmann & Lenzen, 2018). In recent decades, production markets have largely shifted to China and low- and middle-income countries causing an increasingly large geospatial separation between consumer markets and production markets (Jiang & Green, 2017; Wiedmann & Lenzen, 2018). This has led to the emergence of global supply chains which have profoundly changed the way commodities are produced and consumed resulting in unexpected repercussions for a wide range of economies, societies, and the environment (Kónya & Ohashi, 2007; Wiedmann & Lenzen, 2018).

By disconnecting the point of consumption from the point of production, the environmental and social impacts of commodities now take place far beyond the borders of a single country (Wiedmann & Lenzen, 2018). This spatial complexity has increased the environmental impacts of many products and raised concerns regarding the feasibility of coupling environmental sustainability and an economy with international trade as its defining characteristic (Fanning et al., 2022; Kónya & Ohashi, 2007; Steinberger et al., 2012). Today, up to 70% of the environmental and social impacts of goods do not occur in the country of consumption (Wiedmann & Lenzen, 2018). For instance, more than 50% of land-use from food consumption in EU countries occurs in other countries (Wiedmann & Lenzen, 2018). As a result, increased consumption and affluence in rich countries have led to the transgression of global planetary boundaries, but through international trade, the environmental impacts of this consumption are most felt in poorer countries (Fanning et al., 2022; Wiedmann et al., 2020).

In this thesis, we explore the influence of international trade on shifting the environmental impacts of two systems critical to a sustainable society: the food system, and the plastic waste management system. These two systems are chosen due to the importance of trade within their core function. More than 25% of global food production is traded internationally, while 80% of the world's population is believed to live in countries that are dependent on international food trade (Kummu et al., 2020a). Concurrently, the food system is one of the largest generators of plastic waste due to the quantity of food packaged and the short lifespan of single-use packaging (Andrady & Neal, 2009a; J. P. Schweitzer et al., 2018). Moreover, more than one third of plastic waste generated in EU countries is destined for export from the country in which it was generated, while other countries such as Japan and the United States also rely heavily on international to manage their plastic waste (Bishop et al., 2020a; Velis, 2015).

1.2 Impacts of trade on the food system and plastic waste

Sustainability feeding a growing population and reducing the stranglehold plastic waste has on the environment are perhaps, next to climate change, two of the greatest challenges of our time (Amaral-Zettler et al., 2020; Ban, 2012).

The food system is responsible for 30% of global anthropogenic greenhouse gas (GHG) emissions, occupies 40% of global land, and drains 70% of freshwater annually, making it a driver of climate change, biodiversity loss, and freshwater depletion (Springmann et al., 2018a; Willett et al., 2019a). The current structure of the food system causes these global impacts to not be distributed according to consumption, however. For instance, more than 50% of the land-use impacts and 80% of water consumption associated with food consumption in EU countries occur outside of EU borders (Chaudhary & Brooks, 2019; Dalin et al., 2017). Despite these environmental drawbacks, global food trade is thought to have brought stability to the food system since its rapid expansion in the 1970s (Clapp & Moseley, 2020).

Economists have noted that repeated shocks to the system, including the 2008 financial crisis and the 2019 Covid pandemic, were handled remarkably well by the food system, illustrating the resilience created by international trade (Clapp & Moseley, 2020; Torero, 2020). Nevertheless, concerns regarding the aforementioned environmental costs of international food trade are challenging the ideologies of an economically efficient trade-centric food system (Clapp, 2017b). The potential for food systems based on local food production to mitigate the environmental burdens of the current food system while revitalizing shorter supply chains has thus become a critical subject of research (Schönhart et al., 2009).

Concurrently, the food system is one of the largest generators of plastic waste due to plastic's short cyclical applications such as the packaging of food. The use of plastic benefits longer preservation of food, but at the cost of generating large amounts of single-used plastics (Andrady &

Neal, 2009a). This application of plastic, among many others, led to a rise in plastic consumption and plastic waste generation throughout the 20th century and early 21st century that outpaced the rate of plastic waste treatment and recycling, resulting in 79% of all plastics ever made to be landfilled or dumped in the environment (Geyer et al., 2017a). As a result, plastic pollution has permeated every Earth system, giving rise to a new ecosystem called the plastisphere (Amaral-Zettler et al., 2020). Countries have enacted policies to mitigate this trend by diverting waste away from landfills, maximizing recycling, and focusing on reducing waste generation (Y. Chen et al., 2021; Kahlert & Bening, 2022; Mrkajić et al., 2018). To meet these legislative ambitions, high-income countries have utilized international trade to export plastic waste since it is a convenient and affordable option to divert waste from landfills while increasing recycling rates (Dauvergne, 2018). Indeed, most major exporters of plastic waste are allowed to include exported waste within their recycling metrics, making plastic waste exports an attractive management pathway (Bishop et al., 2020a; Brooks et al., 2018a). To date, international trade has displaced at least 236 Mt of plastic waste since 1988, largely from high-income countries to China until the country implemented a plastic waste import ban in 2017 (Brooks et al., 2018a). Since the ban, other low- and middle-income countries have increased their role as major plastic waste importers (Brooks et al., 2018a). This exported waste has placed immense pressure on the waste management infrastructure of importing nations, even hindering its development, resulting in higher rates of plastic mismanagement and pollution (Browning et al., 2021; Marks et al., 2020; Sarpong, 2020). Despite the dynamics of international plastic waste trade being well understood, quantitative studies of this system on global plastic leakage to the environment remain scarce.

1.3 Research questions

Given the aforementioned pressures placed on the environment by trade within the food system and plastic waste system, this dissertation contributes to the current body of knowledge by answering the following research question:

> *How is trade affecting the environmental impacts of the food and plastic waste systems?*

The scientific literature has extensively covered the role of international trade in disconnecting food consumption and food production impacts (Brown et al., 2017; Friel et al., 2020; Kummu et al., 2020a). The food sector is therefore an interesting sector to explore the repercussions of increasing trade barriers, offering a new perspective. In contrast, the impact of international trade on plastic pollution has been scarcely explored (12–14). Global plastic pollution studies have frequently relegated this aspect of the plastic waste system to study limitations due to its relatively small volume compared to global plastic waste generation (Velis, 2015).

Therefore, to answer the main research question and offer new insights for the scientific community we split the research into the following sub-research questions (RQ's):

RQ1: How would global agricultural land-use change if countries could reduce their dependence on food trade?

RQ2: How does food consumption in the Netherlands contribute to domestic and international plastic pollution?

RQ3: How does international trade contribute to global plastic pollution?

RQ4: How are international trade policies affecting the contribution of trade to global plastic leakage?

1.4 Methods - Physical analysis of anthropogenic and environmental systems

To tackle the impacts of trade, tracking the mass of various products as they move both spatially and through the economy is key. To do so, spatially explicit numerical models are developed making use of spatial data at various scales such as national-scale population, agricultural land, crop availability, and yield data, but also higher resolution data including sub-national population and hydrography (30 arcseconds resolution each), and metropolitan-scale trade infrastructure.

To model the effects of trade in the food system and the plastic waste sector, this thesis primarily follows a material flow analysis (MFA) approach. MFA, or substance flow analysis (SFA), is a mass balance exercise that maps material mobilization, use, and excretion between the economy and the environment (Van der Voet, 2002). It is useful when the objective of a study is to provide insights regarding the management of specific materials (Van der Voet, 2002). This has led MFAs to be increasingly used for policy development as they can highlight critical factors straining the coexistence of anthropogenic and natural systems (Bringezu & Moriguchi, 2018; Patrício et al., 2015). In the case of mapping flows through international trade to the natural environment, including a spatial dimension to the MFA is crucial because each stage of the mobilization, use, and excretion of a material occurs in different geographic regions (Patrício et al., 2015). Such spatially explicit MFAs typically incorporate geographic information system (GIS) data at various resolutions to assign a spatially dependent property to all mass fluxes of the system (Müller et al., 2014).

All research chapters integrate dynamic modeling systems within the broader MFA approach. Multiple models or mathematical frameworks have been connected, each representing different stages of the wider system in order to better understand how each stage interacts with the remaining system (Pires et al., 2011). This approach helps understand how environmental systems respond to anthropogenic forcings under different conditions, allowing research to formulate schemes to minimize negative repercussions (Huang & Chang, 2003). The models developed in this dissertation can receive dynamic information to provide unique insights regarding how the observed systems can be altered to mitigate negative externalities or to produce a desired output. To explore potentially desirable outputs, this dissertation also makes use of scenarios on multiple occasions. Predictive 'what-if' scenarios are elaborated to gain insights into the limitations of available data offering a sensitivity range, while explorative scenarios are used to understand the outcomes of changing system structures (Börjeson et al., 2006). These scenarios highlight certain critical points within integrated models, offering insights into how inputs or intra-system relationships would need to be altered to achieve the desired outcome (Pires et al., 2011).

1.5 Overview of the thesis

Chapter 2 addresses RQ1 and explores a scenario where international trade is non-existent and determines the agricultural land-use of all countries. By doing so, we can gain insights into which countries are most reliant on shifting impacts away from their borders to ensure adequate food supply to their populations. In this analysis, global food consumption patterns are shifted to the EAT-Lancet diet to ensure a nutritious apport to the populations of each country. Production and consumption interventions are then proposed to reduce national agricultural land-use for countries that would exceed their available agricultural land.

Chapter 3 addresses RQ2 and focuses on plastic waste generated within the food system. Since plastic food packaging is one of the largest generators of plastic waste annually, further understanding how food consumption and plastic leakage are linked could help develop more effective mitigation measures moving forward. This chapter determines the plastic intensity of the Dutch diet to estimate the annual production of plastic waste. The plastic waste generated is mapped throughout the entire Dutch post-consumer plastic waste supply chain, including the exported fraction to ultimately quantify how food consumption in the Netherlands contributes to plastic leakage to aquatic environments.

Chapter 4 addresses RQ3 exploring plastic leakage caused by all plastic waste generated globally. Plastic waste trade accounts for all countries are mapped to determine the final import destinations of plastic waste and their management fate in these countries. This mismanaged imported waste that reaches the aquatic environment is then connected back to the original waste generators to better understand which countries are most contributing to plastic pollution via international trade.

Chapter 5 addresses RQ4 and presents an analysis of key policies regarding the international plastic waste trade and how they have contributed to changing the role of international trade on global plastic pollution since 2012, thereby temporally contextualizing the results of chapter 4. The work explores how policy decisions aimed at reducing plastic leakage may unintentionally cause an increase due to a lack of standardization and harmonization in plastic waste management metrics and policies.

Chapter 6 briefly synthesizes the results of each research chapter and highlights their contribution to answering the main research question of the dissertation. A reflection on the main research question is then presented, followed by discussions of the limitations and potential future research avenues of the dissertation.