Impact of food waste and loss reduction on sustainability targets

Submitted for presentation at the 24. Annual Conference on Global Economic Analysis "Global Food System: Opportunities and Challenges", June 23 to 25, 2021

DRAFT – not suitable for citation

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Abstract

With increasing global food demand and growing pressure on our natural biophysical planetary boundaries, policy makers agreed on the United Nations Sustainable Development Goals (SDG) to be achieved in 2030 to foster sustainable global development. One of the SDG objectives aims at reducing food waste and loss by 50% at the global level which could contribute to achieving a more sustainable food system. As we have observed globally a change in countries' commitments to multilateral agreements and strategies in recent years, our objective is to investigate the contribution to sustainable development one global player (e.g., the EU) could make in the absence of global commitments and strategies.

Therefore, this study assesses the impact of food waste and loss reductions on economic, social and environmental market indicators and the resulting trade-offs, for a selection of regions across the world. In doing so this study aims at analysing the impact of a global food waste loss reduction strategy versus an EU-only strategy by particularly shedding light on the impact on virtual trade and related leakages of e.g., greenhouse gas emissions and land use changes.

For this purpose, a recursive dynamic Computable General Equilibrium is employed which includes numerous additional biobased activities splits such as waste and recycling to facilitate the analysis of the circular impact of food waste and loss reductions.

Keywords:

Food waste and loss, dietary change, computable general equilibrium, sustainability

1 Introduction

With increasing global food demand and growing pressure on our natural biophysical planetary boundaries, policy makers agreed on the United Nations Sustainable Development Goals (SDG) to be achieved in 2030 to foster sustainable global development. While on the global level the agricultural sector accounts for significant shares of freshwater usage, global land use and greenhouse gas emissions, around 30% of global agricultural and food production is lost during the production process or wasted at retail and consumer level (FAO, 2019). Consequently, reducing food waste and loss could contribute to achieving a more sustainable food system. The FAO (2014) estimates that annually, the economic cost of food waste amounts to 2.6 trillion USD, equivalent to 3.3% of global GDP. Furthermore, non-market biophysical benefits arising from reductions in food waste and loss in terms of land and water savings are to be expected. From an environmental perspective, also reducing activities in emissions intensive activities such as primary agriculture is expected to play a positive role in curbing greenhouse gas emissions. The European Union (EU) recently published their 'farm2fork' strategy that includes policy objectives to reduce food waste and loss in the EU member states. However, in recent years we observed globally a change in countries' commitments to multilateral agreements and strategies. Even though the EU is an important global actor that could largely contribute to reaching SDG waste and loss targets, in the absence of global commitments and strategies, EU's action related to reducing food waste and loss might have only limited effects at world level.

Therefore, the objectives of this study are (1) assessing how food waste and loss reductions impact on economic, social and environmental market indicators and the resulting trade-offs, for a selection of regions across the world and (2) analysing the impact of a global food waste loss reduction strategy versus an EU-only strategy. This study particularly aims at shedding light on the impact of virtual trade and related leakages of e.g., greenhouse gas emissions and land use changes.

This paper therefore uses an advanced variant of a neoclassical CGE model to examine how changing consumer choice patterns, including changing dietary habits and food waste, together with food loss reduction, affect food consumption, productions as well as social and environmental market indicators and the resulting trade-offs, for selected regions worldwide. Additional modelling innovations to consider food waste and loss reduction by region by 2030, while changing diets consider the impact of food substitutions under conditions of unchanged food balances compared to a baseline from 2020 to 2050. The modelling approach is also enhanced to compute the impact on biophysical/environmental indicators as well as to trace the virtual trade of resources.

This article is structured as follows. Section 2 introduces the model and data used to assess the impact of changes in consumer behaviour and describes the experimental design, while Section 3 presents the results focusing on economic, social and environmental indicators. The final section summarises the results.

2 Methods

2.1 Modeling framework and aggregation

This study employs an advanced CGE neoclassical model known as the Modular Applied GeNeral Equilibrium Tool (MAGNET) (Woltjer et al., 2014), which is a recursive dynamic variant of the standard Global Trade Analysis Project model (Hertel 1997). This version of the model is benchmarked to version 9 GTAP database with base year 2011 (Aguiar et al. 2016) which covers 57 production sectors and 140 countries and regions. To enhance the analysis of the circularity of food waste and loss reductions, a biobased variant of the standard GTAP database consisting of numerous additional biobased activities splits including waste and recycling (Philippidis et al., 2019) is used. Furthermore, this study makes use of a nutrition module in MAGNET (Rutten et al., 2013b, 2014) in order to control the balance of food nutrients in the diet when changing consumer dietary patterns (i.e., red meat reductions).

To enable the tracing of food consumption on environmental impacts such as land use and emissions, the CGE model is extended by module that calculates footprints such as the average per capita per year land use related to household food consumption (Philippidis et al. 2021). These footprints consider all economy-wide inter- and intra-industry intermediate input purchases within and between food and non-food production chains, as well as the use of scarce resources. Furthermore, this module allows the tracking of non-tradable virtual commodities (land, water, emissions) along the food supply chain associated with household food consumption.

With a focus on food waste and loss as well as consumer diets, this study keeps all agricultural and food activities as disaggregated as possible. Furthermore, it includes a detailed depiction of bio-based activities and their non-biobased counterparts, while other sectors such as manufacturing and services are aggregated as shown in table 2.

Table 2: Overview commodity coverage

Arable crops, horticulture	rainfed paddy rice; rainfed wheat; rainfed other grains; rainfed oilseeds; rainfed raw sugar; rainfed vegetables, fruits and nuts; rainfed other crops; irrigated paddy rice; irrigated wheat; irrigated other grains; irrigated oilseeds; irrigated raw sugar; irrigated vegetables, fruits and nuts; irrigated other crops; crude vegetable oil
Livestock, meat and fish	cattle and sheep; pigs and poultry; raw milk; cattle meat; other meat; dairy; processed fish products
Fertiliser	fertiliser
Other food and beverages	sugar processing; vegetable oils and fats, processed rice, other food and beverages
Other 'traditional' bio-based activities	fishing; forestry; wood products; paper products; textiles & clothing
Bio-mass supply	energy crops; residue processing; pellets; by-product residues from rice; by-product residues from wheat; by-product residues from other grains; by-product residues from oilseeds; by-product residues from horticulture; by-product residues from other crops; by-product residues from forestry; Municipal waste
Bio-based liquid energy	1st generation biodiesel; 1st generation bioethanol; 2nd generation thermochemical technology biofuel; 2nd generation biochemical technology biofuel; bio-kerosene
Bio-based and non-bio-based animal feeds	1st generation bioethanol by-product distillers dried grains and solubles; crude vegetable oil by-product oilcake animal feed
Renewable electricity generation	bioelectricity; hydroelectric; solar and wind
Fossil fuels and other energy markets	crude oil; petroleum; gas; gas distribution; coal; coal-fired electricity; gas-fired electricity; nuclear electricity; electricity distribution; kerosene
Other sectors	chemicals, rubbers and plastics; other manufacturing; aviation; other transport; food services; services

Source: Own elaboration.

The 140 countries and regions are aggregated to 13 regions: USA and Canada (USACAN); Brazil (Brazil); Rest of Latin America (RLatAme); Northern Africa (NoAfrica); Sub Saharan Africa (SSAfrica); European Union (EU); Rest of Europe (REurope); Russia (Russia); Middle

East (MidEast); India (India); China (China); Rest of Asia (RAsia); Oceania (Oceania). This regional coverage accounts for the major continents and players on world food and energy markets.

2.2 Baseline and scenario overview

A long run reference scenario transition pathway from 2011 to 2050 is designed and implemented based on the Global Energy and Climate Outlook (GECO) published by the Joint Research Centre of the European Commission (Keramidas et al., 2018, Weitzel et al., 2019). This baseline characterises a climate and energy pathway to 2050 by implementing detailed assumptions regarding real macroeconomic growth, population change, fossil fuel prices, energy usage and efficiency by types of activity and region, emissions changes, and land productivities (details in table 3).

Table 3: Summary of key market driver implemented in the baseline

Exogenous driver	Description
Region-wide productivity	Region-wide productivity calibrated to regional real rates of GDP (Keramidas et al., 2018).
Capital stock	Baseline assumes a fixed capital-output ratio so that capital stock changes at the same percentage rate as GDP
Population	Reginal population changes are taken from Keramidis et al. 2018
Labour force	Baseline assumes a fixed long-run employment rate so that labour force changes at the same percentage rate as regional population
Carbon tax	Global increases in the carbon tax ($/tonne) by time period on all activities (Weitzel et al., 2019).
Energy input shifters	Calibrated input-output technology shifters to mimic energy balance trends by energy type and usage (Keramidas et al., 2018).
Land productivity	Land productivity changes are taken from the Shared Socioeconomic Pathway 2 (SSP2) (O'Neill et al. 2014)
Energy final demands	Exogenous final energy demand taste shifters to mimic pathway trends (Keramidas et al., 2018).
Global fossil prices	Fossil fuel price changes are taken from Keramidis et al. 2018
Biofuel mandates	Exogenous mandates on first-generation and advanced-generation biofuels by region

Source: Own elaboration.

A further refinement to the baseline was the recreation of a plausible food demand pathway consistent with the baseline narrative by implementing downward shifters on the income elasticities as per capita kilocalorie daily intake exceeded reasonable expectations, particularly in high-income and rapidly growing countries. Income elasticity shifters have also been used to ensure the same rates of catch-up in kilocalorie intake in emerging regions as observed in the initial baseline. In addition, we assume no dietary changes in the period 2030 to 2050 with regard to the shares of kilocalories of red meat, white meat, dairy and fish products in total daily per capita food consumption, to consistently account for the substitution effects of food commodities and the related effects on household budget and environmental indicators in the simulated scenarios and the baseline.

In comparison to this baseline we simulate a set of scenarios to assess the impact of food waste and loss reductions on three pillars of sustainability:

1) all regions across the globe meet the SDG no.12.3 target and reduce food waste and loss by 50% in 2030, cost equals 5% of the value of production
2) only the EU meets the SDG no.12.3 target and reduce food waste and loss by 50% in 2030, cost equals 5% of the value of production
3) Sensitivity analysis: Re-running scenarios 1) and 2) by adding cost related to food waste and loss reducitions equal to 0%, 1%, 5% or 10%

FAO (2011) provides estimates along five steps of the supply chain from food loss at the farm level to food waste at the consumer level for seven commodity groups and seven aggregated regions. Using this information, we calculated the food loss and waste rates weighted by agriculture and food production for the aggregation chosen in this study. Food waste and loss shares differ largely between regions, commodity groups as well as stages of the supply chain. The highest food waste shares are observed in high-income countries at the consumer level, while low-income countries tend to have the highest shares of food losses due to agricultural and production and post-harvest losses. Food waste and loss shares are the highest for horticultural commodities including fruit and vegetables as well as roots and tubers, and for cereals.

The simulation of food waste reductions by commodity category is done using household budget share shifters that endogenously adjust to meet targeted household consumption reductions as applied by Philippidis et al. 2019 to assess food waste impacts. This approach considers food waste as a decrease in the quantity or quality of food resulting from decisions and actions of food services and consumers. A reduction in food waste thus corresponds to reduced expenditure on food as well as reduced input demand from the food service sector, represented by an increase in the input use efficiency of the food service sector. In addition, food waste generated at the retail level is introduced into the model as an input saving shock.

In line with Kuiper and Cui (2020), this study considers food loss as a decrease in the quantity or quality of food resulting from decisions and actions of food producers in the supply chain. Therefore, we assume that reducing food losses associated with agricultural production losses and post-harvest losses will lead to an increase in the productivity of primary agricultural commodities such as arable crops, horticulture, and livestock production, while reducing food losses associated with processing and packaging will lead to an increase in the input use efficiency of primary agricultural commodities used for food processing (e.g., meat and dairy production, vegetable oils, cereals and fruit and vegetable products (other food) imposed as an input saving productivity shock. Our first scenario (FWL) simulates a 50% reduction of food waste and loss until 2030 in line with the SDG target 12.3. Philippidis et al. 2019 clearly shows that reducing food waste and loss is not cost-neutral. However, to the best of our knowledge, there are no cost estimates at country or global scale, so we use an ad-hoc approach (Philippidis et al. 2019). Therefore, by assuming that compliance cost per unit of sales could trigger the required behavioural changes in food consumption and food production, we make a rough assumption about compliance cost equal to 5% of the value of production. Specifically, we assume that the costs arise on the supply side, e.g., through changes in production as wells as packaging processes, investments in improved storage facilities or means of transport. Implementing these determined costs into the cost function increases the unit costs of the inputs for each relevant agricultural and food commodity.

3 Results

3.1 Economic impact

3.2 Social impact

3.3 Environmental impact

4 Discussion and conclusion

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