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Doing More With Less: Cutting Food Loss and Waste in the EU and Its Impact on Food Security

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ABSTRACT

In September 2025, the European Parliament and Council signed the law of the Revision of the EU waste framework directive, which includes also reductions for food loss and waste (FLW). This comes at a time of concern over the EU's strategic autonomy for its agrifood sector. Taking a cradle-to-grave approach, this paper combines official FLW statistics with recent advances in simulation modelling to quantify the impacts of two FLW cuts scenarios on EU food availability, affordability, and stability. Compared with a business-as-usual baseline, average EU household per capita food budget savings and self-sufficiency of up to €192 and 0.82%, respectively, are observed, accompanied by falling average EU food production of up to 2%. With the inclusion of FLW behavioural market adjustment costs (taxes), average EU food producer price falls of up to 1% are lower than reported in previous studies, whilst in a handful of member states, consumer food prices rise marginally. This hitherto unforeseen outcome is a signal for anticipating and ensuring adequately tailored social protection schemes for the most vulnerable.

1 | Introduction

As the world continues to grapple with the challenges of global population growth and climate change, actions to reduce food loss and waste (FLW)[1] not only provide a ready solution for strengthening food security, but also offer clear synergies with efforts to reduce anthropogenic emissions from farming and protect natural resource degradation (European Commission 2023). In this context, objective 12.3 of the United Nations' Sustainable Development Goals (SDGs), targets the halving of per capita food waste by 2030 (United Nations General Assembly 2015).

The causes of FLW are complex and diverse, relating to both technological and social factors. For example, in developed economies, food losses may arise due to supply chain inefficiencies (e.g., post-harvest, packaging, transportation) or contractual obligations requiring farmers to supply produce to retailers meeting pre-specified quality and aesthetic requirements (Porter et al. 2018). Meanwhile, household waste has been linked to numerous non-price determinants including poor purchase planning, food aesthetics, cultural and lifestyle factors (e.g., Lusk and Ellison 2017; Schanes et al. 2018).

In the EU, the recent Vision For Agriculture and Food (European Commission 2025) calls for FLW reductions that have gained greater momentum in light of recent crises that have beset the EU and its agriculture sector, putting food security back on the agenda and heightening calls for greater 'strategic autonomy' in the EU (European Commission 2022).[2] In 2020, the COVID pandemic triggered supply chain disruption with the enforcement of social distancing (Laborde et al. 2020). More recently, the Russian invasion of Ukraine led to the weaponisation of

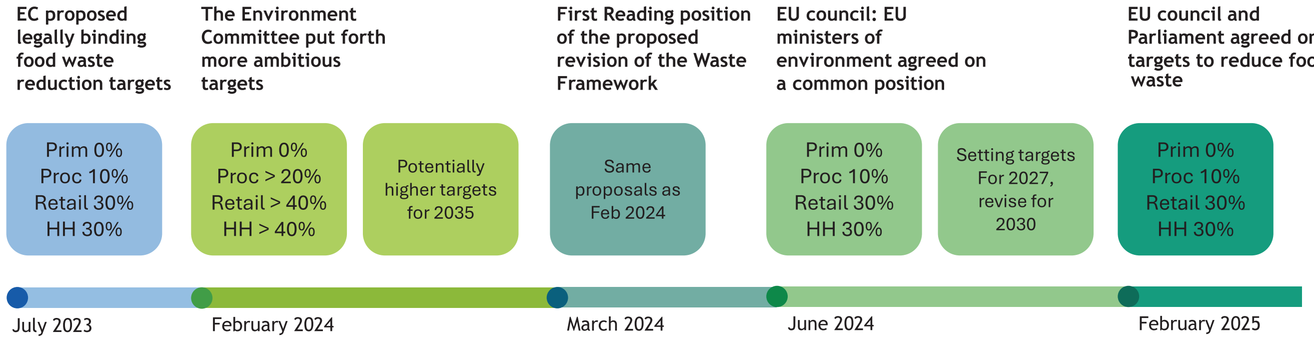

FIGURE 1 | Timeline of EU food waste reduction legislative proposal.

food supplies, whilst rising costs faced by farmers, largely driven by energy and fertilizer price hikes, further exacerbated market instability and fuelled food price inflation. Moreover, the increasing frequency and severity of climate-related disasters carry broad consequences for food and agricultural markets. In response, the EU has made food security one of the core objectives of the EU strategic agenda 2024–2029 (European Council 2024a).

In July 2023, the European Commission proposed legally binding FLW reduction targets for Member States as part of the revised Waste Framework Directive (European Commission 2023). The proposals targeted a 10% reduction in food processing and manufacturing losses (FPML) and a 30% reduction in per capita retail losses and household waste (RLHHW) (restaurants, food services, households) by 2030 compared to the amounts generated in 2020 (European Parliament 2024a) (Figure 1). In February 2024, the European Parliament Environment Committee adopted a more ambitious stance, proposing a minimum 20% reduction in FPML and a minimum 40% per capita reduction in RLHHW by 2030 in comparison to the annual average generated between 2020 and 2022. The Committee also urged the Commission to set targets for primary food production and propose further reductions for 2035 (European Parliament 2024b). The Parliament maintained these proposals in their first reading position in March 2024 (European Parliament 2024c). In June 2024, the EU Council eventually settled on a 10% reduction in FPML and 30% reductions in RLHHW per capita by 2030 relative to the reference period of 2021–2023 (European Council 2024b). The Council also left room for setting targets for edible food waste by 2027, to be reviewed alongside the 2030 targets (European Council 2024c). In February 2025, the European Parliament provisionally approved the EU Council's June 2024 proposals (European Council 2025a). Following that, in March 2024, the committee provisionally approved the agreement from interinstitutional negotiations. In September 2025, the European Parliament and Council signed the law of the Revision of the EU waste framework directive (European Council 2025b).

Within the shifting sands of the EU legislative and policy debate surrounding FLW, prospective impact assessments quickly become out of date when evaluating the potential implications for EU food markets. Thus, a key objective of this paper is to employ the latest developments in simulation modelling of FLW to examine these policy proposals with a particular focus on food availability (i.e., supply and demand dynamics), food affordability (i.e., household budget impacts), and food stability (i.e., self-sufficiency). Two policy package scenarios are implemented (Section 3.3) with specific FLW reduction targets at different leverage points along the food supply chain stage.[3] These scenarios are compared with a 'business-as-usual' baseline to 2030. In the context of the current policy debate, this is the first paper to consider FLW reductions along the entire food supply chain. A further important novelty is the explicit representation of waste reduction 'adjustment costs' to consumers and producers, which hitherto have been largely ignored in previous impact assessments.

The rest of this paper is structured as follows. Section 2 gives an overview of the state-of-the-art of the current FLW modelling literature. Section 3 explains the methodology and data employed in the current study. Section 4 presents the results. Section 5 provides a discussion of the results and gives some conclusions.

2 | Literature Review

The Food and Agriculture Organization of the United Nations (FAO) (2019a, 2019b) note that implementing FLW reductions can improve all four dimensions of food security, namely, availability, access, utilization, and price and supply stability. Its direct impact can, however, be diverse, depending on where the reduction occurs within the supply chain or the geographic region. For example, in low-income countries with higher food insecurity, mitigating food loss carries greater importance, whilst in developed economies, end-of-chain food waste dominates total FLW (Food and Agriculture Organization of the United Nations 2019a, 2019b). To characterise the supply and demand dynamics of FLW reductions and gain insight on the resulting market driven impacts, calls for the use of a simulation model. Indeed, the elevated level of importance of FLW on the political agenda has, over the last decade, prompted a steady increase in the number of simulation model impact assessments.

A more direct comparison of these studies is, however, somewhat obfuscated by a number of issues. At the most fundamental level, the credibility of a model rests upon the data employed. With a lack of universally accepted conceptual definition of FLW (Hoehn et al. 2023) due to perceptual differences marked by one's disciplinary background (Cattaneo et al. 2021), or culture (Fabi et al. 2021), coupled with a varied range of accounting methods to estimate FLW by commodities (De Laurentiis et al. 2021), modelling studies often exhibit different starting estimates on what actually constitutes FLW. Further differences relate to divergences in the scenario design (i.e., assumed magnitude of the FLW cuts, coverage of food chain FLW leverage points), as well as differences in key model assumptions (i.e., how FLW reductions are modelled) and modelling structures (e.g., partial equilibrium (PE) versus computable general equilibrium (CGE) models). Notwithstanding, there is already a broad consensus that cutting waste results in increased food affordability and availability (e.g., Rutten et al. 2013; Rutten and Kavallari 2016; Barrera and Hertel 2021; Kuiper and Cui 2021), whilst reducing emissions, agricultural production and employment (e.g., Rutten et al. 2013; Rutten and Kavallari 2016; Barrera and Hertel 2021; Kuiper and Cui 2021).

Two recent example PE studies illustrate different approaches to measuring food waste in applied studies. For example, focusing on consumer food waste, Barrera and Hertel (2021) impute a time series of ex post values through a micro system of equations linking observations on biological energy requirements, body weight and food availability. To make ex ante baseline (i.e., business as usual) projections of food waste within their agricultural PE model, a logistical functional form is estimated to link the share of daily per capita calorific intake that is wasted, to the key modelling driver of changing incomes per capita. The authors subsequently project medium- to long-term food waste across different global regions, whilst the food security implications of food waste reductions are assessed under conditions of 'segmented' versus 'open' trade markets. In the latter case, they find that efficient food distribution through open trade considerably reduces food prices and greatly mitigates the prevalence of undernourishment, especially in vulnerable areas. In contrast to the imputed approach of Barrera and Hertel (2021), Latka et al. (2022) take an implicit approach by assuming secondary data estimates of 'avoidable' (the majority) and 'unavoidable' waste shares by food groups (Vanham et al. 2015) into their agricultural PE model (CAPRI). In relation to food security, the authors show the beneficial impacts of an exogenous 50% cut in avoidable food waste, resulting in both EU consumer demand-(up to 31% for pulses, roots and tubers) and price-reductions (up to 5% for cereals), whilst supply reduces proportionally less due to rising animal feed demand and EU exports to third markets.

In a similar manner, there are examples of CGE (i.e., economy-wide) applications of FLW reductions. Whilst CGE models often lack the sectoral resolution of their agricultural focused PE counterparts, they are closed system macroeconomic models that can fully capture the synergies and trade-offs arising from policy interventions. More specifically, they explicitly represent all stages of the food supply chain and the interlinkages with the rest of the economy (i.e., non-food input usage in agriculture and resource competition effects with non-agricultural sectors). Furthermore, these models capture 'rebound' effects from changing household consumption patterns on non-food items, arising from savings on food expenditures, while more recent methodological and data developments (see below) allow modellers to examine circularity issues relating to waste collection, treatment and reuse.

There are CGE studies that exclusively focus on food waste reductions (e.g., Rutten et al. 2013; Rutten and Kavallari 2016) or food loss reductions (Kuiper and Cui 2021) borrowing secondary estimates of FLW 'rates' from published sources (e.g., Food and Agriculture Organization of the United Nations 2011, 2019a, 2019b). Focusing only on food losses, Kuiper and Cui (2021) show the benefits for food availability in developing economies. Other CGE work (e.g., Gatto et al. 2023) introduces greater detail by tracking biophysical FLW flows to the specific model drivers along the supply chain and consequently the transaction value flows within the model database. Even more recently, this treatment has been further extended to capture not only FLW generation but also waste processing and (circular) treatment stages (Bartelings et al. 2024).

From a review of the above literature, however, two methodological gaps remain relatively unattended, which this paper seeks to address. Firstly, given the close attention in the recent policy debate to reducing FLW at all stages along the food supply chain, there are no recent policy-driven studies that quantify the collective impacts of said reductions with respect to food security. To keep abreast of the current policy debate (Section 1), there is a need to examine FLW reductions throughout the entire food chain (European Commission 2025), encompassing production, processing, retail, distribution, and consumption. This paper therefore builds on the CGE modelling work of Bartelings et al. (2024) and Bartelings and Philippidis (2024), which integrate Eurostat satellite accounts of 'cradle-to-grave' FLW at different leverage points and explicitly link these to rational producer/consumer choices between food consumption and food waste behaviour, the latter of which is modelled as the demand for waste collection services. In this way, the act of wasteful behaviour by agents along the supply chain is entirely consistent with, and embedded within, the theoretical economic structure of the model.

A second issue relates to the modelling representation of food waste reductions, which in the aforementioned studies, lacks treatment of the adjustment costs (Food and Agriculture Organization of the United Nations 2019a, 2019b) to producers and consumers, thereby potentially overestimating food price reductions (i.e., food affordability) arising from FLW reductions. Economic theory suggests that rational optimisation behaviour by producers and consumers generates a negative externality in the form of waste, which requires a correction in the form of an internalisation of the market adjustment costs by the appropriate economic agent. Thus, contrary to the prediction of falling food prices due to (intermediate and final) demand reductions, an additional layer capturing per unit adjustment costs is expected to introduce a countervailing (at least partially) inflationary impact on food prices.

The CGE modelling literature above (with two exceptions—see below) typically captures costless adjustments either via preference shifters to reduce food waste (motivated by 'moral suasion') or exogenous ('manna from heaven') productivity improvements to simulate food loss cuts. In response to this oversimplification, a CGE study of food waste by Britz et al. (2014) treats the consumer adjustment costs associated with reduced waste, with the labour-leisure trade-off (i.e., preparation times, increased purchase planning). On the producer side, Philippidis et al. (2019) model compliance costs (e.g., labelling, packaging) arising from loss reductions as a fixed rate of the sales value. In both cases, however, the behavioural mechanisms are heavily stylised and/or ad hoc. To maintain consistency with the theoretically

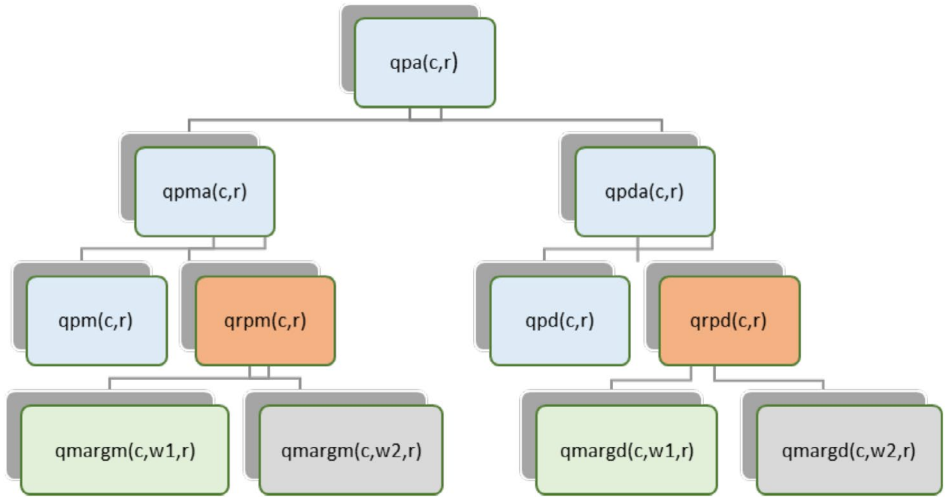

FIGURE 2 | Nesting structure for private household waste demands in MAGNET. *Source:* Bartelings and Philippidis (2024).

consistent behavioural equations of the model, this paper follows the work of Bartelings and Philippidis (2024) in that adjustment costs, proxied by per unit waste behaviour taxes, are levied on consumer and producer demands for FLW collection services (i.e., waste behaviour). In this way, the adjustment costs to actors along the supply chain arising from targeted reductions are now internalised within the market.

3 | Materials and Methods

The methodology is described in the following sections, starting with the underlying database and model mechanisms (Section 3.1), the modifications to the model to add FLW behaviour (Section 3.2), and the baseline and scenario design (Section 3.3).

3.1 | Database and Model[4]

As a starting point for the current paper, the Global Trade Analysis Project (GTAP) multi-region economy-wide CGE market simulation model and global database is employed. The GTAP database (Aguiar et al. 2019) follows the principles of a social accounting matrix (SAM) covering 65 activities and 141 regions complete with primary factor, intermediate input, and final demand value transactions measured at basic, producer, and purchaser's prices. Each of these macroeconomic tables is connected via gross (two-way) bilateral commodity-specific trade flows inclusive of taxes, subsidies, and transport margins to yield 'cost-insurance-freight' and 'free-on-board' prices. To close the circular flow of transactions in each macroeconomy, the balance of the capital (i.e., savings less investments) and the current (trade) account equate to leave a zero balance of payments.

The accompanying GTAP model (Corong et al. 2017) is comparative static and employs the behavioural tenets of neoclassical economic theory (optimisation) to characterise representative agents' behaviour in response to changing relative prices.[5] Price transmission along (domestic and foreign) supply chains is inclusive of exogenous market instruments (i.e., taxes/subsidies). Under the principle of multi-stage budgeting, intermediate or final demand behaviour can be broken into a series of sequential decision stages ('nests') using convenient functional forms. Final (consumer) demand in GTAP employs a more flexible constant difference of elasticities (CDE) function that differentiates private consumer behaviour employing non-unitary commodity-specific price- and income-elasticities of demand. To ensure a general equilibrium, market clearing and accounting equations (i) equate supply and demand in each market, (ii) ensure zero long-run economic profits for each activity (subject to constant returns to scale), (iii) equate macroeconomic output, expenditure, and income transactions and (iv) impose a net-zero balance of payments.

The Modular Applied General Equilibrium Tool (MAGNET) (Woltjer and Kuiper 2014), which employs GTAP at its core, is a recursive dynamic model more suitable for capturing structural economic change over time through different rates of accumulation of capital investment. MAGNET uses a series of binary switches to activate methodological and data advances in those areas of pertinence to the research question at hand. For the current study, a key advance of MAGNET over GTAP is to model with more precision the operational boundaries of the food system within the macroeconomy (i.e., agricultural land and labour market rigidities; specific crop and livestock production nest structures; competition effects for biomass across food, feed, energy and materials uses; EU biomass policies, final demand patterns for food).[6] Moreover, the extended GTAP data used in MAGNET includes additional activity splits to (*inter alia*) horticulture, livestock, fertilisers and feeds.

3.2 | Modelling and Data for Food Loss and Waste[7]

MAGNET activates a dedicated waste module (Bartelings et al. 2024; Bartelings and Philippidis 2024) that characterises FLW behaviour within the nesting structure of food chain actors (intermediate inputs) and consumers (final demands). Taking the example of consumers (see Figure 2), there are final (Hicksian cost-minimising) demands for each composite food commodity '*c*' ($qpa_{c,r}$), split by domestic ($qpda_{c,r}$) and foreign origin ($qpma_{c,r}$). In the case of composite food demands of domestic origin (for example), it is separated into consumed food ($qpd_{c,r}$) and its accompanying 'waste demand' ($qrpd_{c,r}$) by an (inelastic) substitution elasticity.[8] Waste demand is represented as a demand for domestic margins, which is included as an additional cost akin to a collection cost by the collecting service 'w' ($qmargm_{c,w,r}$). This 'rational' representation of waste behaviour directly drives the estimate of the quantity of household waste for commodity '*c*' (see data discussion below).

The structure of food loss generation by producers on intermediate input demands is analogous to the above approach and is described in Section S3.3 of the Supporting Information document. Thus, primary (post-harvest) waste behaviour is on intermediate demands for primary agricultural commodity '*c*' in primary agricultural industry '*i*' (where $c=i$). Processing waste demands are on intermediate demands for primary agricultural commodity '*c*' by food, feed, energy, and material-related industries. Finally, retail waste behaviour is driven by intermediate demands for food-related commodity '*c*' by trade, transport, and food services sectors.

To characterise the adjustment costs to consumers and producers, a 'waste behaviour tax' is inserted into the price transmission equations (Bartelings and Philippidis 2024). Employing the consumer nest example in Figure 2, a single exogenous waste behaviour tax separates the basic and purchase unit price on household domestic (qrpd) and imported (qrpm) waste generation demands (i.e., demands for waste collection services). The same approach is used in the production nest, which separates per unit basic and purchase prices of intermediate input demands for waste collection services. In this way, the cost of this 'market failure' (i.e., FLW) is now internalised within the price of the food commodity '*c*', thereby incentivising agents to reduce FLW at different leverage points along the supply chain.

Accompanying these final and intermediate waste demand drivers in the model is a satellite database of EU FLW by different leverage points along the food supply chain.[9] Employing Eurostat (2022) data, FLW estimates are available by stage of the food chain for each Member State. Three supply stages are considered: post-harvest losses, process and manufacturing losses, and retail and transport losses. In addition, estimates of end-of-chain household-driven consumption of 'in-home' and 'out-of-home' waste are available. Since the Eurostat data is not product-specific, a mixture of detailed Material Flow Analysis (MFA) data from the Joint Research Centre (JRC) of the European Commission (Caldeira et al. 2021; De Laurentiis et al. 2021) and household expenditure shares in the MAGNET database were used to apportion demand-driven FLW by agents to the specific primary agricultural classifications in the MAGNET model database. Post-harvest losses are linked to own use of primary inputs '*i*' in the primary agricultural sectors '*j*' (i.e., where $i=j$). Processed food losses are linked to intermediate purchases of any non-retail activities that use over 1% of the total domestic intermediate demand of the primary food commodity (excluding 'own use' of primary input '*i*' into activity '*j*' (i.e., $i=j$), which is considered as post-harvest losses). Finally, retail and transport losses are linked to the use of food commodities in the food service, retail, and transport sectors. Finally, 'in-home' household waste is directly driven by final food demand purchases, whilst 'out-of-home' waste is driven by household demands for the 'food services' commodity. To convert these waste quantity flows into transaction values compatible with the MAGNET database, green and grey waste collection and treatment costs per tonne are taken from Hoornweg and Bhada-Tata (2012) who published average waste treatment costs for low-, medium-, and high-income countries.

3.3 | Baseline and Scenario Design[10]

An EU focused regional aggregation is implemented, with the non-EU regions split into broad continental groupings. Taking advantage of MAGNET's additional activity splits, the study includes a coverage of 80 commodities showing a more granular view of agri-food activities across the entire supply chain (crops, livestock, food processing, food services, and trade services), as well as relevant inputs in food production, alternate uses of food (i.e., feed, fertiliser, bio-based materials, and energy), and its circularity (waste collection and treatment services).

A 'business-as-usual' baseline assumes a continuation of current policies, regulations, and market trends, shaping the wider bioeconomy up to 2030. This baseline is divided into an update period (2014–2020) and a projection period (2020–2030). As noted in the introduction, the choice of time frame coincides with the European Commission's target period for food waste reductions. Baseline changes are largely driven by a consistent set of historical and projected economic (e.g., real GDP, labour force), demographic (i.e., population), energy market (prices and demands), and climate policy (emissions) projections from the long-term Global Energy and Climate Outlook (GECO) 'reference scenario' (Keramidas et al. 2021) of the European Commission. Further data sources are used to implement additional land and forestry productivity shocks, agricultural support payments, and biofuels policy shocks and changes in per capita food preference trends. Importantly, 2020 Eurostat estimates of FLW by EU member state and food supply chain leverage points are exogenously targeted in the first period of the baseline and serve as a basis of comparison for the FLW cuts. Comparing with the baseline in 2030, two scenarios of FLW cuts compared with 2020 levels are designed (Table 1). The 'Agreed-Cuts' scenario reflects the June 2024 proposal which was provisionally approved by the European Parliament in February 2025. The 'Ambitious-Cuts' scenario is based on the February 2024 proposals by the Environment Committee.

4 | Results

4.1 | Baseline: Slow but Consistent Total FLW Growth

According to Eurostat (2022), total FLW in the EU amounted to 56.98 million tonnes in 2020, which equated to 127 kg per capita. For this study, a business-as-usual baseline projection of the total food waste quantity from 2020 to 2030 is carried out in order to establish a realistic starting point for our analysis of potential reduction measures in 2030. Changes in real GDP and population drive rising incomes per capita, final demands, production, and investment. The response of final food demands to rising income per capita is conditioned by the commodity-specific income elasticities of demand in the model. Thus, the baseline projects moderate increases in food waste for the EU, reaching 57.04 million tonnes in 2030, or 127.8 kg per capita (not shown).

The reason for the slow rise in total FLW from 2020 to 2030 is due to the strong switch by households toward out-of-home food consumption, particularly in the less mature but faster growing EU member states. Indeed, Figure 3 shows that the average share of EU household waste from out-of-home consumption (i.e., food services waste) is also growing from 14.4% in 2020 to 17.8% in 2030. As a result, household waste *per euro of food expenditure* in the decade to 2030 declines in these regions, which impacts total EU food waste generated (Bartelings and Philippidis 2024). Food losses consistently rise to 2030 across different leverage points of the supply chain (Figure 3), although household food waste (in- and out-of-home consumption) still remains by far the largest share, accounting for 36.5 million tonnes (64%) in 2020, falling to 34.9 million tonnes (61%) in 2030 (Figure 3).

When examining the composition of food losses across the two time periods, the food categories of fruits and vegetables emerge as the primary source, collectively accounting for approximately 80%, 56% and 35% of post-harvest, processing and manufacturing, and retailing and distribution food losses, respectively (Figure 3). In terms of household food waste, vegetables and fruits are once again the two largest single commodity sources.

4.2 | Scenarios: Minor Macroeconomic Impacts in All EU Member States

The key underlying result is that the reductions in FLW in each scenario has a very minor impact on real GDP across the EU member states. This is to be expected, since although the

TABLE 1 | Overview of the food waste reduction targets per proposal and per scenario versus 2020.

		Primary harvest loss	Processing & manufacturing loss	Retail & distribution loss	Household waste
Proposed targets	Proposal, July 2023	0%	10%	30%	30%
	Proposal, February 2024	0%	> 20%	> 40%	> 40%
	Proposal, June 2024	0%	10%	30%	30%
Executed scenarios	Scenario 1: Basic	0%	10%	15%	15%
	Scenario 2: Half-way house	0%	10%	30%	30%
	Scenario 3: Ambitious	0%	25%	50%	50%

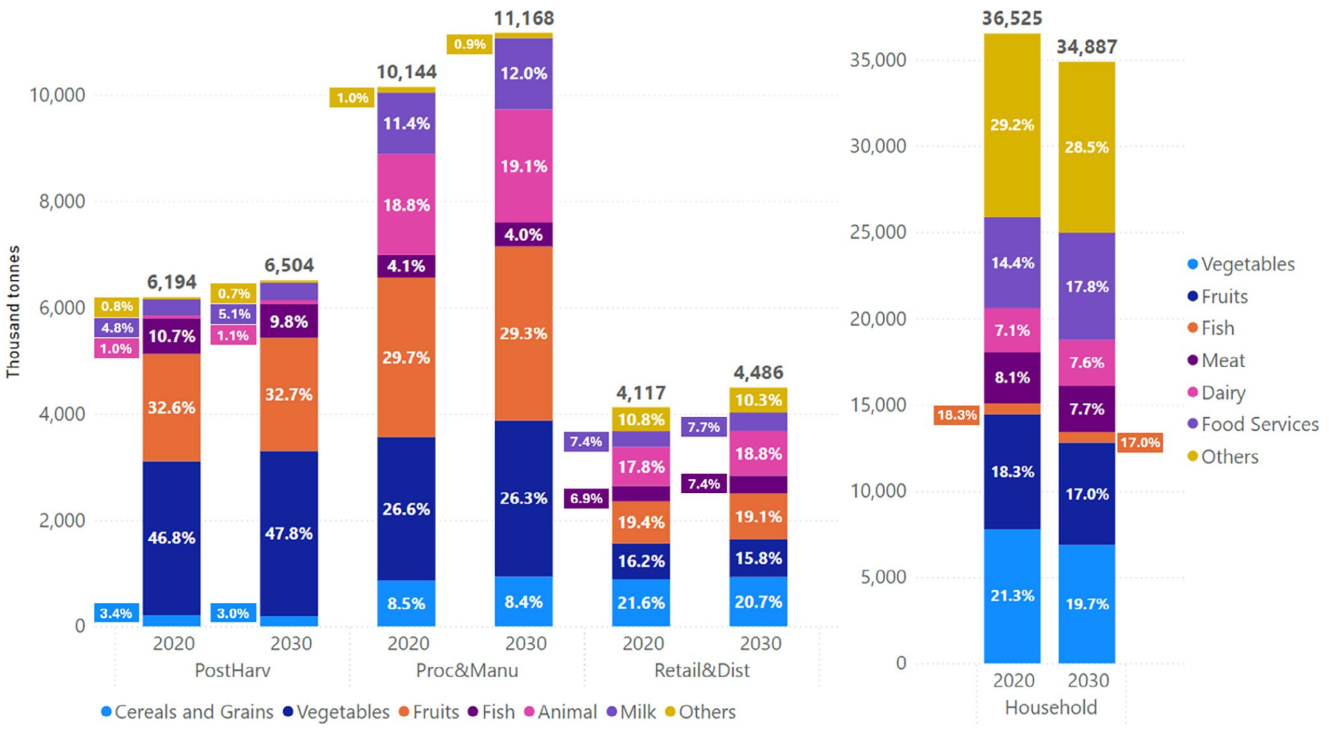

FIGURE 3 | FLW quantities in the baseline for 2020 and 2030 by leverage point and commodity.

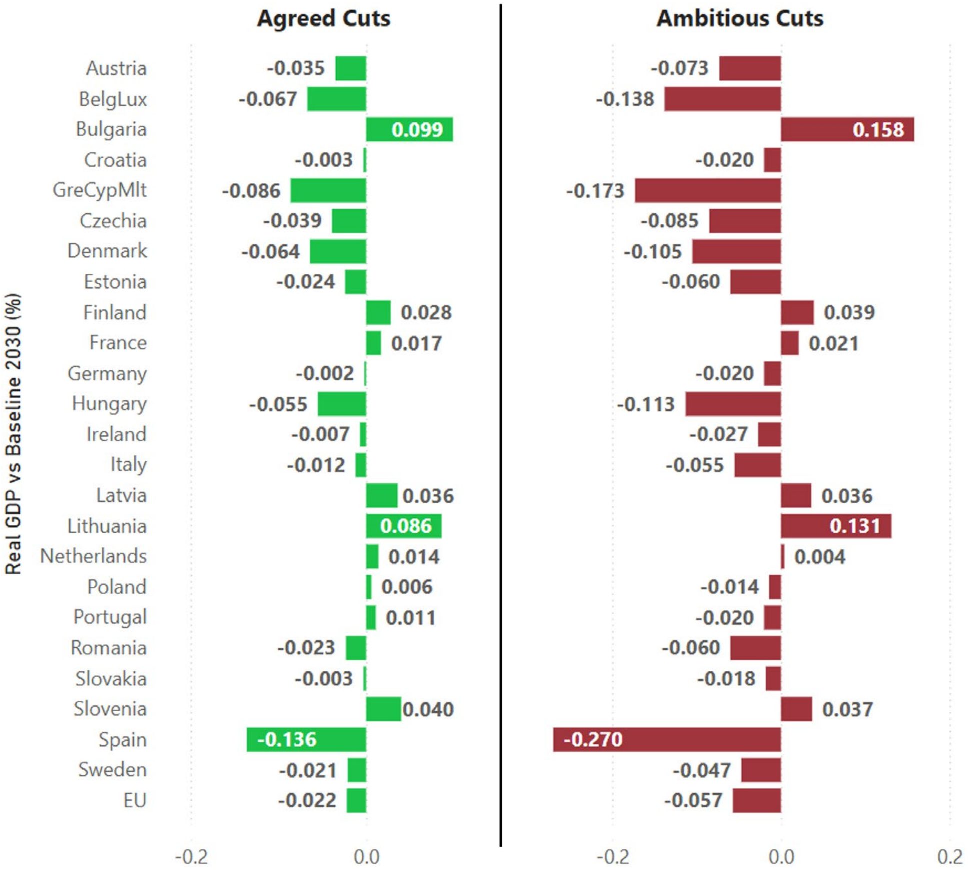

FIGURE 4 | Changes in real GDP compared with the baseline in 2030.

combined share of agriculture, fishing and food processing and services activities is 8.3% of EU GDP,[11] the reductions in demand for these sectors' output is relatively moderate. This is because waste rates represent a relatively minor part of agriculture and food output, whilst the waste reductions are only partial (i.e., considerably less than 100%).

For the EU aggregate, Figure 4 shows that the net impact on real GDP in both scenarios compared with the baseline, is slightly negative (−0.02% and −0.06% in the agreed and ambitious scenarios, respectively). Assuming unchanged household savings rates in the baseline and the scenarios, moderate household savings (see Section 4.5) on food consumption are spent on non-food goods. The net impact on real growth in each of the EU member states reflects the pattern of food and non-food demand between domestic and imported substitutes. EU household food demands are largely sourced from within the EU single market, such that the resulting reduction in agrifood production will be mainly felt across the EU regions (particularly the more export-oriented EU members). On the other hand, non-food demands exhibit a comparatively higher extra-EU trade component, suggesting a certain leakage effect from the compensating rise in EU household non-food demands.

4.3 | Scenarios: Households Drive FLW Reductions

In Figure 5, are presented the reductions in FLW compared with the baseline in 2030, for each scenario. In the Agreed-Cuts scenario, the estimated reduction in EU FLW is approximately 13.1 million tonnes by 2030, equivalent to a 23.1% reduction in FLW in the baseline. For processors, retailers, and households, the resulting waste taxes are €13/t, €51/t, and €59/t, respectively (not shown). As expected, higher taxes are levied on retailers and households, which face deeper cuts. At the upper threshold ('Ambitious-Cuts'), it is estimated that 23.5 million tonnes of FLW are saved by 2030 (41.3% reduction). With higher loss and waste cuts, taxes on processors, retailers, and households rise to €29/t, €123/t, and €158/t, respectively (not shown). The Eurostat data show that the household is the largest single leverage point share of total EU FLW and undergoes the highest percentage cuts in the scenarios. As a result, just over 70% of the total FLW saving comes from household food waste in Agreed-Cuts and Ambitious-Cuts scenarios (Figure 5).

4.4 | Scenarios: Falling Food Prices, but Not Everywhere

To illustrate the mechanics behind the food price impacts, separate results are presented for producer prices and consumer prices. The upper part of Figure 5 decomposes the marginal impact on producer prices (vs. baseline) into waste (vertical axis) and loss (horizontal axis) reductions. The former has a negative producer price impact, while the latter has a positive producer price impact. The lower panel of Figure 6 shows the net impact of both effects.

Starting with the lower panel, the average EU producer price of food falls between −0.61% (Agreed-Cuts) and −0.98% (Ambitious-Cuts) by 2030. Decomposing this result by EU member states, there are examples of food producer price falls that are greater than the EU average (e.g., Romania, Czechia, Slovakia, Slovenia), whilst in other EU members, the producer price fall is below the EU average (e.g., Belgium/Luxembourg, Denmark, Ireland).

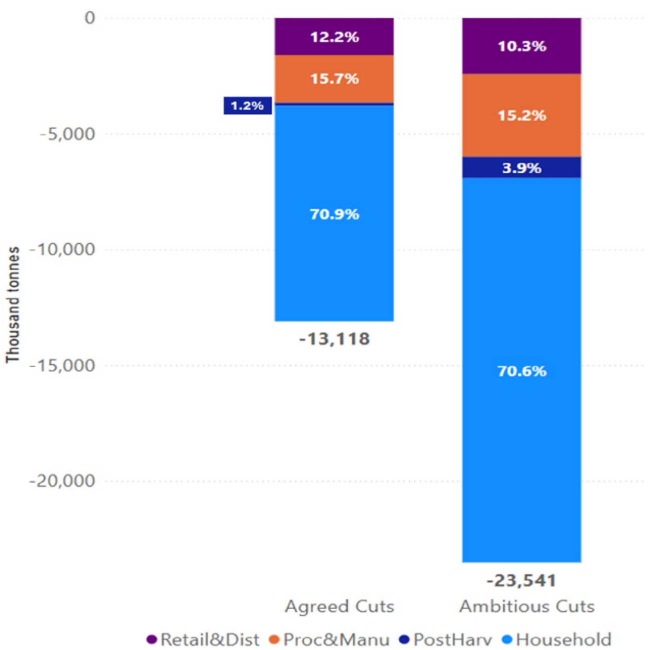

FIGURE 5 | FLW reductions as a share of the total compared with the baseline in 2030.

In the model, there are three key drivers linking FLW reductions to price changes. These are discussed in turn. The first driver is the intensity of household food waste per unit of household expenditure in each EU member state, where higher intensities indicate that per unit of food expenditure, a greater proportion of household food is thrown away. It therefore follows that a uniform percentage reduction of waste implies a larger leftward shift in the household's food demand curve in some EU member states, thereby depressing food production prices by a greater magnitude.

To illustrate, Figure 7 (left hand side) calculates the ratio between household generated waste from home and out-of-home consumption in 2020 (based on the Eurostat satellite data) and the total food expenditure by households (based on the model's own food household transactions data). Across the member states, this generates between approximately 1 and 6 kg of waste per 100 euros of food expenditure. For example, the Figure shows that on average there are 2.694 kg of household waste per €100 of household expenditure in the EU27. Examining the EU member states, households in Romania are the most wasteful (6.083 kg/€100) compared with Spanish households, who are least wasteful (1.112 kg/€100).[12]

The second driver is the share of total domestic food sales purchased by households. Thus, if the household sales share is high within an EU country, then it can be expected that waste reductions by households will have a greater marginal impact on food supply prices. Figure 7 (right-hand side) shows that in value terms, on average 63% of food sales in the EU27 are purchased by households (the rest is employed for feed, energy, and material usage in industries), whilst in Slovenia (Ireland) it is as high (low) as 71.4% (47.5%).

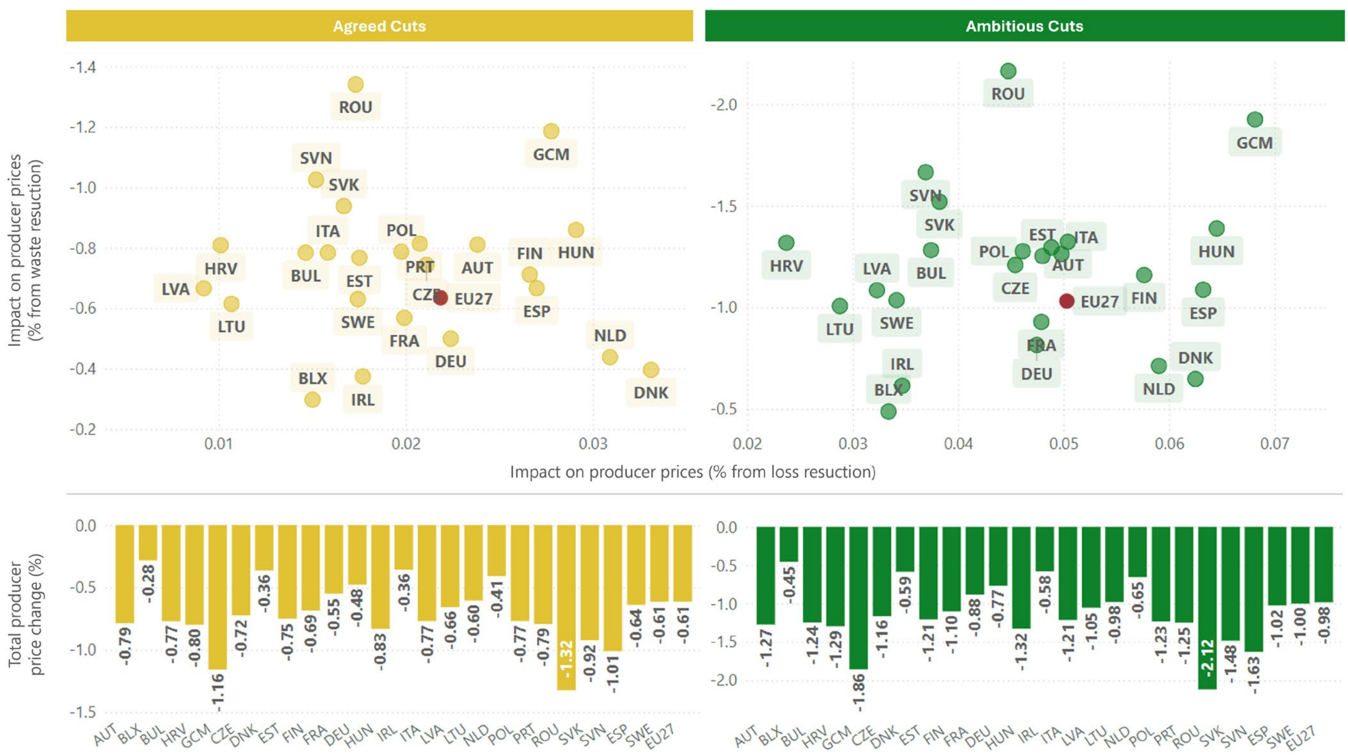

FIGURE 6 | Change in producer food prices (%) driven by waste and loss reductions versus baseline in 2030.

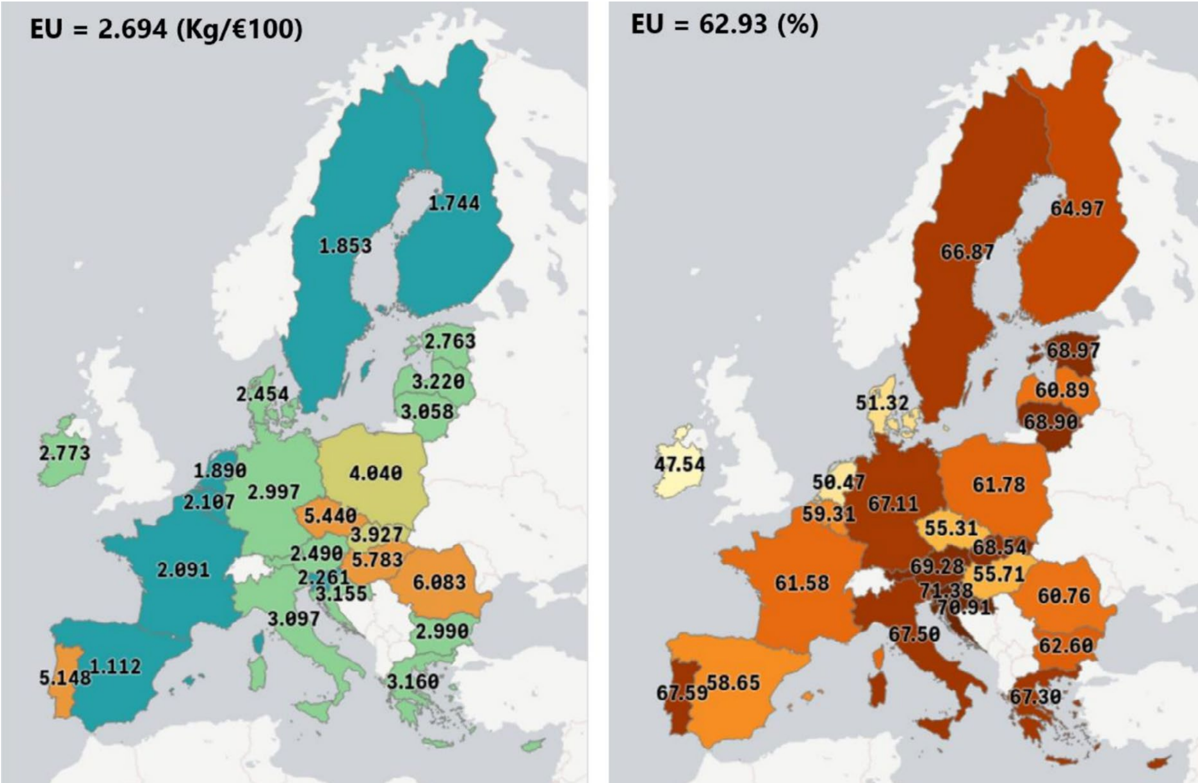

FIGURE 7 | Household waste per 100 euros of expenditure (kg/100€) (left-hand side) and share of domestic food supply (%) purchased by households (right-hand side) – 2020 estimates.

Based on the two drivers above, Romania's producer price fall in Figure 6 is relatively high because its relatively more wasteful households are now cutting back demand more strongly (driver 1 above). In the case of Slovakia, households are considered relatively more wasteful compared with the EU average (driver 1), whilst its share of food purchased by households is also significantly above the EU average (driver 2). For Slovenia, the level of wastefulness of the households is below the EU average, although the share of domestic food supply to households (driver 2) is the highest in all the EU member states. At the other end of the scale, households in Belgium/Luxembourg, Ireland, and Denmark are on or below the EU average for wastefulness, whilst the share of domestic food supply sold to the households is also some way below the EU average.

A third driver of producer prices is the impact of food loss behaviour taxes. Unlike previous modelling studies where loss reductions are treated as productivity improvements that *reduce* per unit food input costs (i.e., Kuiper and Cui 2021), in this study, food loss reduction targets incur additional costs in the form of per unit taxes (leftward shift of the food supply curve). The result is that food loss reductions *raise* producer prices at the margin, rather than reduce them (Figure 6, upper panel). That the effect is small is partly related to the fact that (as stated in Section 4.1) the share of food losses in total FLW is relatively minor, although varying significantly across EU member states. In addition, in the scenario designs, the current proposed level of ambition for food loss cuts is below that of household and retailer waste reductions. The fact remains, however, that the treatment of food losses with accompanying tax costs reverses the falling price trend characterised in previous modelling studies.

It should be noted that these average producer price estimates also mask those price falls by individual agri-food commodities. Figure 8 shows the marginal producer price impacts in 2030 for vegetables. Based on the estimates from the Eurostat data (see also Figure 3), the proportion of waste in vegetables is amongst the highest across the food categories. As a result, the marginal EU average producer price reductions for vegetables (Figure 8) in the Agreed-Cuts and Ambitious-Cuts scenarios are considerably higher than for 'food' as a whole (−2.59% and −4.03%, respectively). Figure 8 also shows the heterogeneity of producer price falls across the EU member states for vegetables, which again are a function of the two drivers discussed above. For example, in the Ambitious scenario, vegetable prices fall by as much as −7.79% in Finland.

In Figure 9, the consumer price impacts are presented. Here we observe that the net downward pressure on producer food prices is further counterbalanced by the waste behaviour taxes on households. The waste behaviour tax on food shifts the supply curve to the left, thereby raising per unit food prices (*ceteris paribus*). The net impact is that consumer price falls are smaller in magnitude compared with producer price falls. Indeed, in the Agreed-Cuts scenario, some EU regions (e.g., Ireland, Netherlands) even exhibit slight relative food consumer price rises. This additional and important effect is not observed in studies that do not account for waste behavioural adjustment costs. Furthermore, the stronger household food waste reduction in Ambitious-Cuts indicates an even stronger

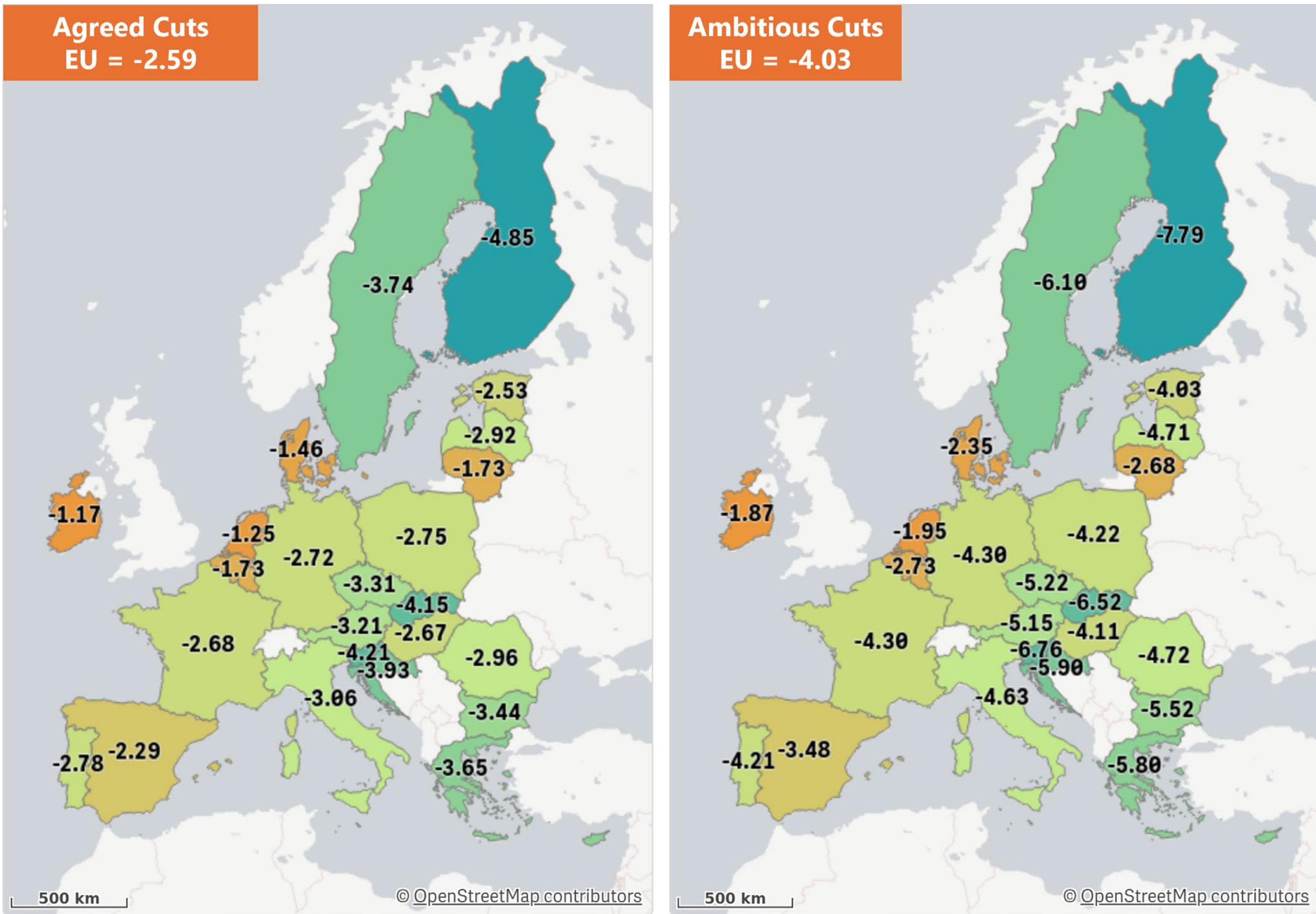

FIGURE 8 | Marginal impacts (%) on producer vegetable prices by member state in 2030 versus baseline.

household adjustment cost, which in a number of EU member states raises food consumer prices in 2030 in four EU member states.

4.5 | Scenarios: Falling Household Food Budget Shares and Rising Food Affordability

As expected, the household food expenditure share is projected to decline in response to food waste reductions. This decline is primarily driven by food quantity reductions and, to a lesser extent, the resulting consumer price decreases (in most regions). The decline in EU average household food expenditure share rises with the level of food waste reduction, ranging from a 3.1% decrease in the Agreed-Cuts Scenario to a 5.1% decrease in the Ambitious-Cuts scenario (Figure 10). Comparing across the EU member states, the relative falls in the food expenditure share are dependent on the pattern of food expenditures on different commodities. For example, in the regions Greece/Cyprus/Malta, Italy, Portugal, and Slovenia, where the relative food expenditure share reductions are highest, high waste products such as vegetables and fruit typically account for a relatively larger expenditure share of the household food basket compared with the EU average (not shown).

In addition to the reduction in food expenditure budget shares, Figure 11 calculates food affordability in each of the scenarios using the metric of household food expenditure savings. Compared with the EU27 per capita food expenditure of €2983 (2014 prices) in the 2030 baseline (not shown), Agreed-Cuts and Ambitious-Cuts scenarios generate average annual per capita food budget savings (2014 prices) of €117 (3.7%) and €192 (6.1%), respectively.[13] Comparing across the EU member states, relative household savings are a function of the pattern of commodity purchases and their respective price elasticities of demand and supply (i.e., magnitude of price and quantity changes with shifting demand and supply curves). It is worth noting again that these savings, although relatively moderate, are fully costed to include the internalised market adjustment costs on producers and consumers. Indeed, in those regions where consumer food price indices rise (e.g., Belgium/Luxembourg, Germany, Ireland, Netherlands—Figure 9), the average household saving in percentage terms is below the EU average.

4.6 | Scenarios: Improving the EU'S Food Autonomy, but Not Without Costs

The marginal impacts of reductions in FLW on the agrifood trade balances are varied and complex. Firstly, it is expected that falls in final food demand by households and intermediate food demand by producers will reduce *extra*-EU import demand, whilst also increasing exports as a greater share of domestic supply is freed up for trade. Secondly, falling final and intermediate food demands also reduce *intra*-EU export demands from those highly export-oriented EU member states that have

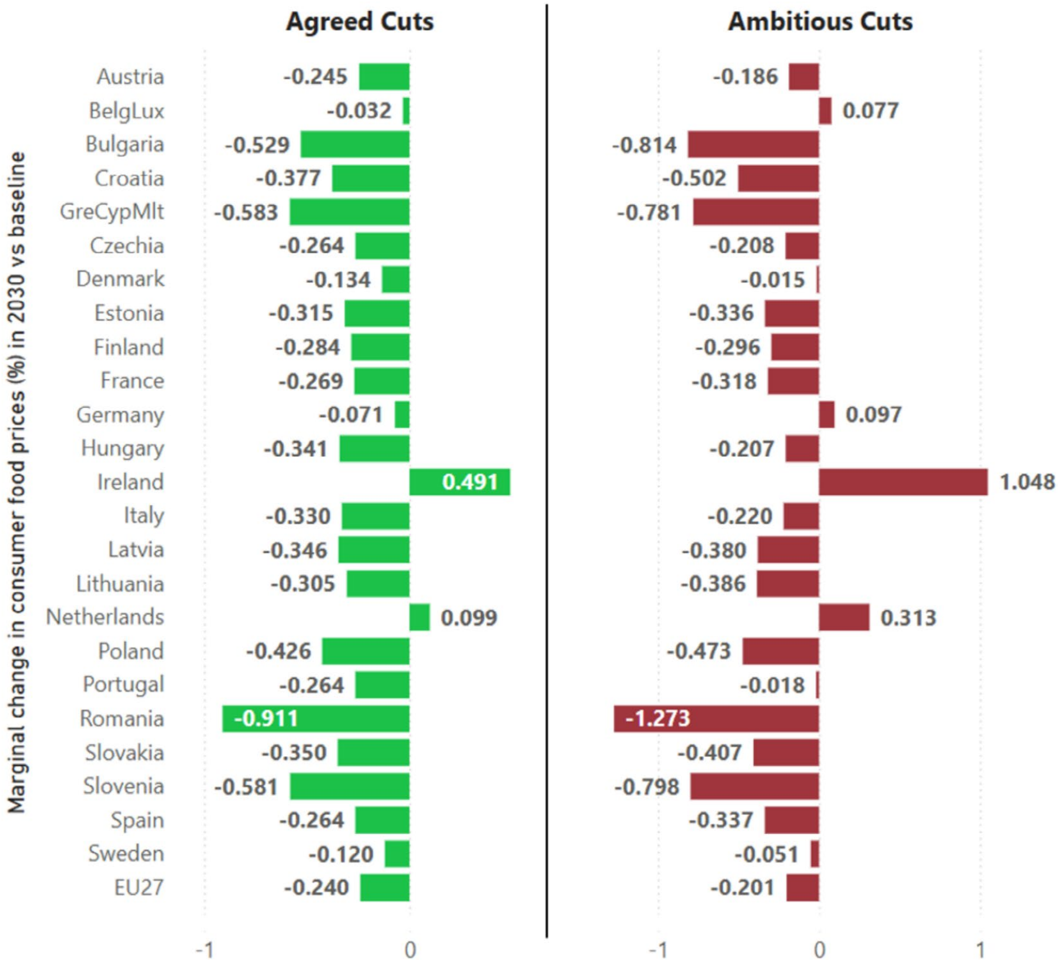

FIGURE 9 | Changes of EU27 agri-food consumer prices (%) compared to the baseline in 2030.

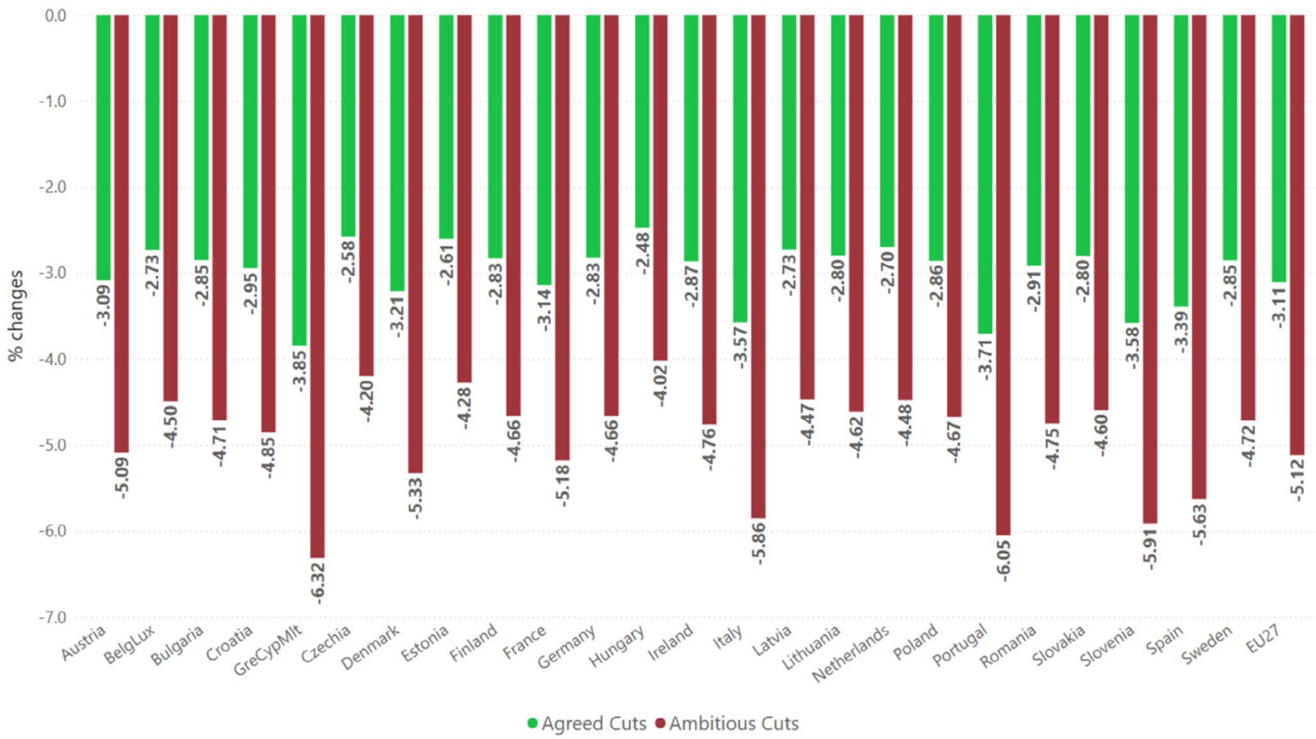

FIGURE 10 | Reductions in EU household food expenditure shares by member state and scenario.

FIGURE 11 | Savings in household food expenditure by EU member state (euros and %) in 2030 versus baseline.

a comparative advantage in particular food products, which in turn will negatively impact that EU region's exports. Finally, the adjustment costs from reductions in food losses raise per unit producer prices (raising the per unit value of exports), whilst also reducing EU food price competitiveness in third country markets (reducing export quantities).

Figure 12 presents the marginal impacts of the two scenarios on the EU member states' agrifood trade balances. For the EU total, the marginal trade balance impacts are decomposed into demand-side (food waste reduction) and supply-side (food loss reduction) effects. The food waste reductions improve agri-food trade balances compared with the baseline, suggesting that of the three drivers described above, the first is the dominating driver in almost all of the EU MS. Indeed, the agrifood trade balance improving effect strengthens with greater household food waste reductions. Moreover, this first driver heavily influences the overall (net) improvements in the agrifood trade balances. Thus, summing over all EU regions, Figure 12 (left side panel) shows that the food trade balance improves by €5244 million (Agreed-Cuts) and €8458 million (Ambitious-Cuts) compared with the baseline.

In two EU regions (Denmark and Netherlands), agrifood trade balances in 2030 deteriorate compared with the baseline. This is largely due to the dominance of the second driver described above, as well as the loss of export competitiveness from the presence of additional adjustment costs (food loss taxes). In the case of Denmark, the relative agrifood trade balance decline is driven by the (export-oriented) white meat (pork) sector (not shown), whilst in the Netherlands, the overall result is driven by trade balance deteriorations in fruit, vegetables, and the 'other processed food' sectors (not shown).[14]

In terms of the isolated impact of food loss cuts, the general trend is that they generate moderate agrifood trade balance deteriorations compared with the baseline owing to reduced price competitiveness of EU exports. For the EU total, cuts in food losses marginally deteriorate the EU agrifood trade balance by between -€132.7 million (Agreed-Cuts) and -€284.5 million (Ambitious-Cuts) (Figure 12, left side panel).

On a commodity-by-commodity basis, for the EU aggregate, all commodity trade balances improve compared with the baseline. This is particularly positive for food commodities where the EU runs a trade deficit.[15] For example, in the case of EU fruit trade the relative trade balance improvements for the Agreed-Cuts and Ambitious-Cuts scenarios are €672 million and €1042 million, respectively (not shown). With a relative improvement in the EU agrifood trade balance, there is a concomitant relative agrifood trade balance deterioration in the non-EU regions. This result is particularly critical in the case of the African region, where its estimated net food export revenues in 2030 (−€26,904 million) decline by a further −€743 million (Agreed-Cuts) and −€1199 million (Ambitious-Cuts) compared with the baseline (not shown).

As a relative measure of the stability of food supplies in each of the EU member states, Figure 13 expresses an aggregate agrifood summary measure for self-sufficiency.[16] Amongst the EU member states, it is highest in Ireland, which produces almost 44% more food than it absorbs domestically (1.438), largely due to surpluses of meat, dairy and fish. In the Netherlands (surplus fruits and vegetables) and Denmark (surplus pork and fish), agrifood self-sufficiency is also relatively high (1.367). In contrast, Slovakia and Slovenia depend on trade for over 25% of their food requirements. Figure 13 shows that in all cases, the EU member

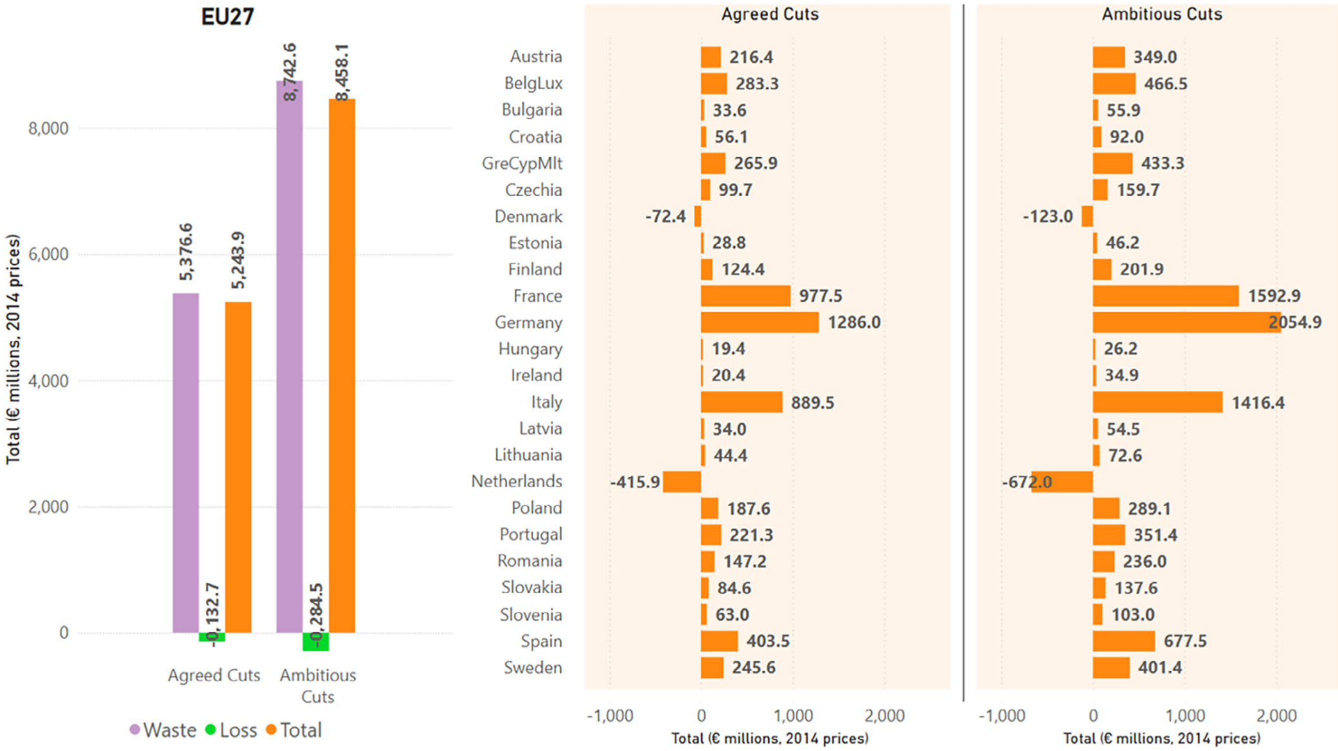

FIGURE 12 | Changes in agri-food trade balances (€ millions) compared to the baseline in 2030.

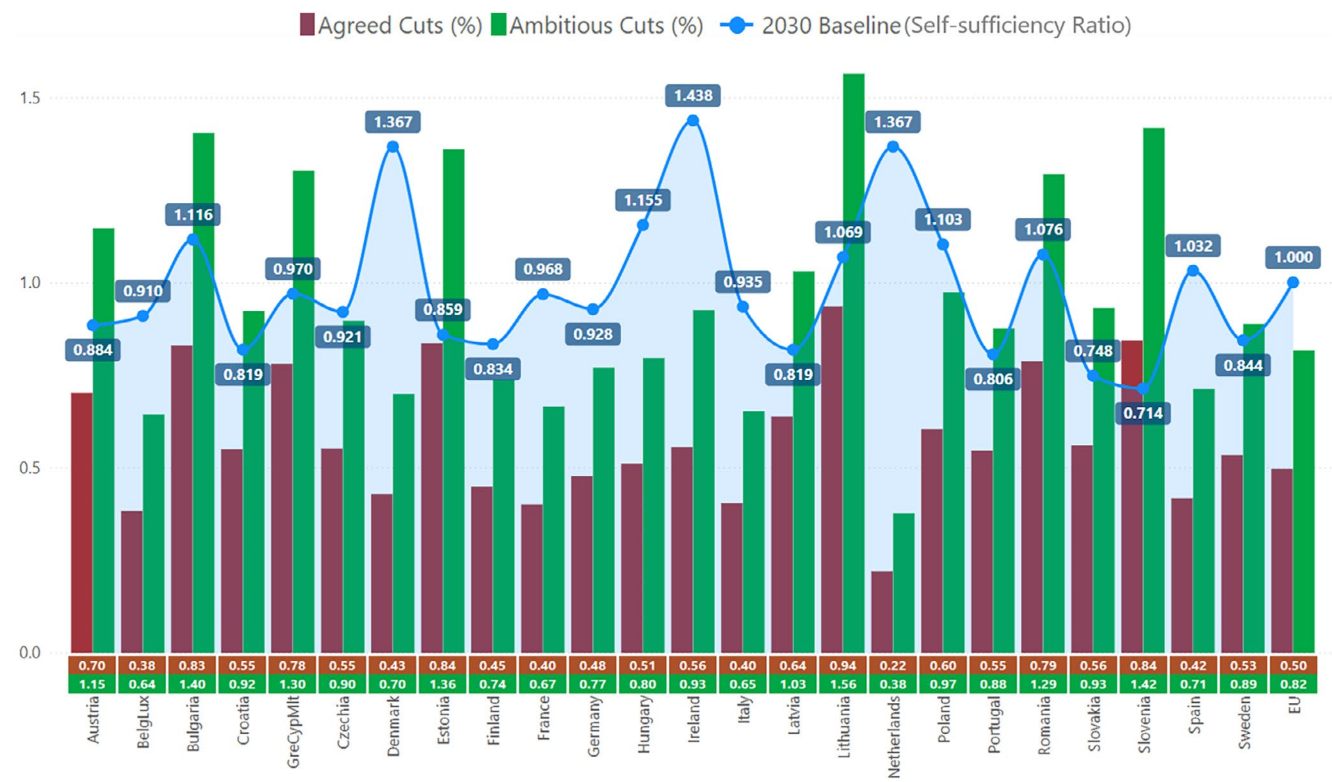

FIGURE 13 | Baseline agri-food self-sufficiency ratio in 2030 and percentage changes in the scenarios compared to the baseline in 2030.

states exhibit improvements in agri-food self-sufficiency. For the EU aggregate, the improvement in agrifood self-sufficiency ranges between 0.50% (Agreed-Cuts) to 0.82% (Ambitious-Cuts).

Those EU member states exhibiting the greatest relative percentage improvements in self-sufficiency have either cut back on household food waste the most (Figure 3—left hand panel) and/or exhibit a higher share of domestic food supply going to final demand (Figure 3—right hand panel) and/or have a lower base level of self-sufficiency in the 2030 baseline.

Finally, an important observation is that the food market dynamics of domestic absorption and trade observed above also irrevocably lead to the general result that the EU's domestic food commodity supply falls when compared with the baseline (consistent with previous modelling studies). This is largely because most EU food is produced for the EU's internal market. The results show that the index of agrifood production falls −1.283% (Agreed-Cuts) and −2.075% (Ambitious-Cuts) compared with the baseline in 2030 (Figure 14). On a commodity-by-commodity basis, the largest production falls are in vegetables, where the rate of upstream and downstream FLW rates are greatest (and therefore the production savings are potentially the largest). Moreover, above EU average food production falls are also recorded for sugar, animal and meat production types and dairy.

5 | Discussion and Conclusions

This study builds on recent data and modelling capacity enhancements (Bartelings et al. 2024; Bartelings and Philippidis 2024) to provide a timely scientific assessment of the EU's plan to legislate food loss and waste (FLW) cuts. Two scenarios ('Agreed-Cuts' and 'Ambitious-Cuts') are implemented for all EU member states. A key result of this paper is that, despite the very minor macroeconomic impact in the EU, efforts to reduce household food waste (vis-à-vis food loss) have a considerably larger impact on food availability, affordability, and stability. In part, this outcome is due to the higher degree of ambition in the EU's proposals geared toward reducing food waste (vs. food loss). Moreover, it is also apparent, according to official Eurostat statistics, that most FLW is concentrated at the end of the supply chain—an observation consistent with United Nations Environment Programme (UNEP) (2024).

At this juncture, we make two further observations. Firstly, the waste reduction estimates presented here should be considered as upper threshold impacts since the food waste reductions do not distinguish between avoidable and unavoidable (i.e., peels, eggshells, bones etc.) components. A similar line of reasoning can be applied in the case of unavoidable food losses owing to natural hazards or disease (Gille 2012). Secondly, consistent with current proposals, the scenario designs prescribe only moderate cuts in food loss, although evidence from Porter et al. (2018) suggests that non-trivial quantities of post-harvest food losses currently discarded on aesthetic grounds could, at very low cost to society, further improve food security. To reduce this source of food loss, the authors recommend the targeting of attitudinal changes to preconceptions of associations between 'ugly' and 'unsafe' food, as well as redressing food supply chain imbalances arising from oligopsony retailer purchasing power.

From a policy perspective, the FLW abatement (tax) costs per tonne reported in this paper vary by leverage point along the supply chain, with a maximum of up to €158/t. These estimates are conditional upon the parametric choices in the producer and consumer nests of the model and are therefore subject to uncertainty. Indeed, a recent OECD study (Nenert et al. 2025) on potential effects and feasibility of achieving different FLW reduction targets provides FLW abatement cost estimates for different countries and regions, based on a thorough literature review and a model-based analysis. A comparison with their median estimate of $500/t puts our estimates at the lower end of the spectrum. Notwithstanding, they find, similarly to the present paper, the need for more evidence, not least to address the uncertainty around the different types of interventions. Furthermore, akin to the implementation of green or dietary taxes, 'waste behaviour' taxation policy faces the challenge of social acceptance. Certain commentators (Carattini et al. 2018; Briguglio 2021) present evidence on the effectiveness of socially responsible taxes, although it has

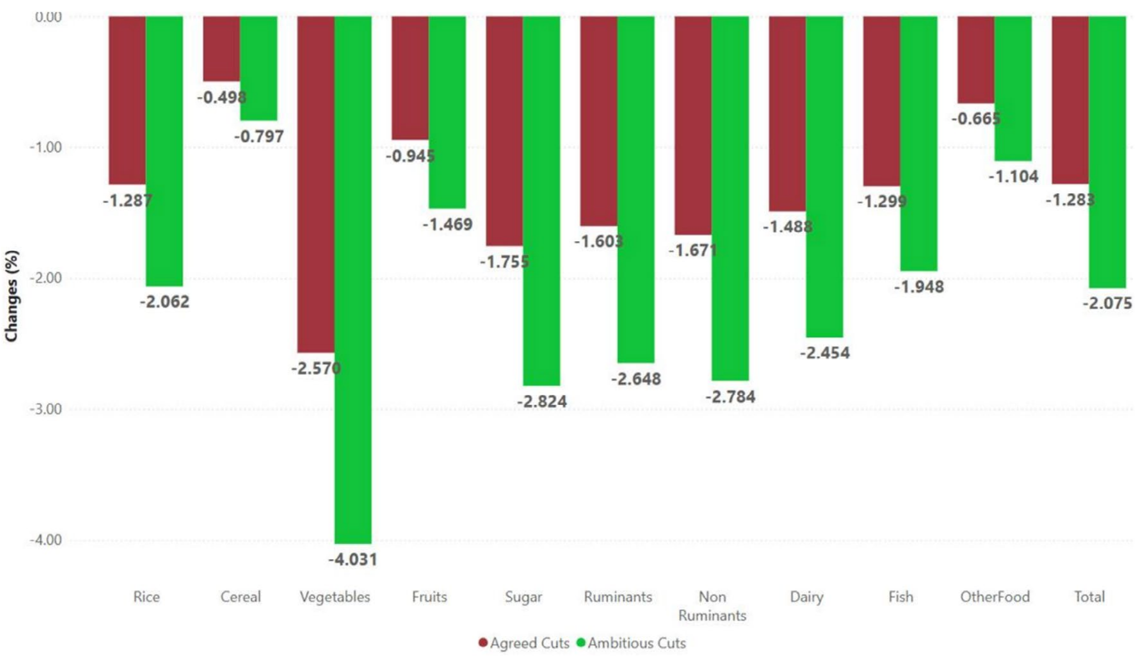

FIGURE 14 | Changes of EU27 agri-food production (%) compared to the baseline in 2030.

been noted that overly high punitive costs could lead to illegal disposal (Briguglio 2021; Hegwood et al. 2023). To make said taxes more palatable to public opinion, governments could sway public sympathy to their use by making clear promises on using waste taxes for socially desirable goals, as seen in examples like Denmark's fat taxes and the UK's sugar taxes (Tselengidis and Östergren 2019). It should also be recognised that in addition to socially coercive corrective market policies, moral suasion to ingrain into the consumer conscious the responsible act of reducing waste (e.g., tackling consumer beliefs, improving food preparation and purchase planning, clearer understanding of food labelling) through educational awareness and publicity campaigns (Vesela et al. 2023; Casonato et al. 2023) constitutes an essential long-term support mechanism to punitive policy packages.

Comparing with previous studies, the food price effects are relatively muted due to the internalisation of waste reduction adjustment costs by different agents. Notwithstanding, this study concurs with the general consensus that FLW reductions reduce food prices, in that the quantity effect (falling final and intermediate food demands) outweighs the price effect (rising per unit food loss taxes). Drilling down further, the results show that the variance in (i) estimated commodity-specific waste rates, (ii) intensities of household wastefulness across member states, and (iii) the share of total domestic food supply purchased by final demands drive heterogeneous supply price impacts by commodities and EU regions. With perfect price transmissions, the general index of food consumer prices also falls in most EU regions. Contrary to previous studies, however, in several EU regions, assumed per unit waste behaviour costs motivate rises in the relative consumer food price index, especially when targeting deeper waste cuts. This is due to the assumed inelasticity of demand substitution between food consumption and food waste (i.e., higher waste cuts require proportionally even higher per unit tax rises).

This more nuanced picture of the impacts of FLW reductions on food prices represents an important departure from previous studies. In the context of recent food price spikes, these adjustment costs pose an additional challenge to achieving food affordability, especially for the most vulnerable EU citizens whose expenditure share on food is typically higher. Policies to mitigate food price rises to poorer sections of society (e.g., food coupons, consumer food subsidies, legislated rises in minimum wages) could also be supported by fiscal and legislative incentives to not-for-profit non-governmental organisations (NGOs) to stimulate food donations to NGOs or improve the transportation, storage and distribution network of food to the neediest (European Commission 2024).

For agricultural producers, the results here support the conclusions of earlier studies, in that economic structural change prompted by FLW reductions accelerates primary agricultural supply declines compared with the baseline. Despite evidence suggesting that food stability (i.e., self-sufficiency) improves (see also below), this result compromises the EU's food supply base (and subsequent dependence on third countries),[17] particularly in times of unforeseen market shocks (e.g., geo-political fragmentation, climate-related risks, a return to more wasteful behaviour). Such an outcome seems at odds with the European Union's current rhetoric for safeguarding strategically important domestic industries. On the other hand, the partial loss of market-based opportunities could hasten along bolder reforms to keep EU farmers on the land and protect rural communities by more explicitly linking farming activity with environmentally targeted non-market goods and services (European Court of Auditors 2024).

Finally, some caveats are in order. Owing to the lack of representation of households by income segments and/or a detailed representation of wage premia by labour skill types, the analysis does not pinpoint the precise distributional implications of the price changes across populations in each of the member states. Moreover, the reported impacts in this study assume that FLW reductions are only committed by the EU. Countervailing FLW cuts in non-EU regions would, however, relatively improve non-EU trade balances at the cost of lower extra-EU agrifood exports. Moreover, based on the evidence of the EU, with more regions engaged in FLW initiatives, food prices would fall more worldwide, although given a lack of detailed FLW data for non-EU regions, the exact magnitude of the price effect is beyond the scope of this study. It should also be noted that given the aggregated definition of agricultural commodities in this study, there is the potential to overstate the EU's self-sufficiency benefit. For example, the fruit or oilseeds sectors consist of numerous product lines for which in some cases the EU will never achieve self-sufficiency (owing to climatic factors). From a technical modelling perspective, a perceived strength of this study is that the mechanisms governing loss/waste behaviour in the demand nests of the model are fully consistent with rational economic theory. Nevertheless, further research is needed to more formally validate the chosen (inelastic) behavioural parametric representation between producer/consumer consumption and the resulting estimates of loss/waste abatement (i.e., tax) costs. Finally, as we show in this paper, the heterogeneous structure of the collected data by supply chain leverage points and EU member states (Eurostat 2023) heavily influences model outcomes. In part, these member state outcomes are influenced by cultural and efficiency considerations. It should, however, be made clear that the technical measurement of FLW remains an imprecise science (European Commission 2019) owing to the definitional issues, respondent- and survey bias.

Author Contributions

Conceptualization and methodology: all authors; Formal analysis and investigation: George Philippidis, Beyhan de Jong; Writing – original draft preparation: George Philippidis, Beyhan de Jong; Writing – review and editing: all authors; Funding acquisition: no funding; Supervision: George Philippidis.

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Conflicts of Interest

The authors declare no conflicts of interest.

Endnotes

[1] There is no universally accepted definition of food loss and waste. This paper follows the FAO and UN SDG definition of supply chain driven 'losses' (i.e., production, post-harvest and processing stages), and end-of-chain 'waste' by households.

[2] At a speech on EU-China relations in March 2023, President von der Leyen urged for the need to 'de-risk' EU trade dependency on third countries.

[3] In our study, we assume that 2020 is the point of comparison for the reductions in FLW since this was the year that was originally designated by the EC in their first proposal of July 2023. At the time of this study, for the baseline targeting (see Section 3.3), this was also the latest year for which published official estimates of FLW were available.

[4] A fuller description of the CGE model framework and accompanying data is given in Section S2 of the Supporting Information documentation.

[5] Agents are represented as productive activities and a single representative (i) private household, (ii) public sector and (iii) investment activity.

[6] In this paper, we restrict ourselves to those modules of pertinence to the study focus. A full discussion of the MAGNET model (including those features discussed here) can be found online at The MAGNET Model | MAGNET (magnet-model.eu).

[7] A fuller discussion of the approach is given in Section S3 of the Supporting Information document.

[8] Logically, close complementarity is assumed between what one consumes and the associated waste that is generated.

[9] A Sankey representation of the FLW data is presented in Section S1 of the Supporting Information document.

[10] Sections S4 and S5 of the Supporting Information document provide additional information on the chosen model aggregation and baseline drivers.

[11] Calculation based on the CGE model database for 2020.

[12] This result is largely driven by the source data used from Eurostat (2022). Further discussion of this data is given in the conclusion section.

[13] The reader should be aware that in view of food price spikes in recent years, these value savings in inflation adjusted terms would be notably higher.

[14] In the GTAP database, 'other food' includes (inter alia) prepared and preserved vegetables, pulses, potatoes; and fruits. Spain also exhibits relative trade balance deteriorations in fruit and vegetables sectors, although relative trade balance improvements in its other food sectors outweigh these effects.

[15] For example, in the 2030 baseline the model estimates absolute trade balance deficits of −€9165 million (fruit), −€5691 million (oilseeds) and −€7669 million (fish and fish products).

[16] Defined as the ratio of the value of domestic commodity supply to the value of domestic and import demands.

[17] The lengthening of food supply chains is also associated with greater supply risk as well as 'leakage' (i.e., footprints).

References

Aguiar, A., M. Chepeliev, E. L. Corong, R. McDougall, and D. van der Mensbrugghe. 2019. "The GTAP Database: Version 10." *Journal of Global Economic Analysis* 4, no. 1: 1–27. https://doi.org/10.21642/JGEA.040101AF.

Barrera, L. E., and T. W. Hertel. 2021. "Global Food Waste Across the Income Spectrum: Implications for Food Prices, Production and Resource Use." *Food Policy* 98: 101874. https://doi.org/10.1016/j.foodpol.2020.101874.

Bartelings, H., and G. Philippidis. 2024. "A Novel Macroeconomic Modelling Assessment of Food Loss and Waste in the EU: An Application to the Sustainable Development Goal of Halving Household Food Waste." *Sustainable Production and Consumption* 45: 567–581. https://doi.org/10.1016/j.spc.2024.01.025.

Bartelings, H., M. van den Bos-Verma, and H. van Meijl. 2024. "Introducing Municipal Solid Waste Streams in a CGE Framework: A Step in the Direction of Circular Economy Analysis." *Journal of Global Economic Analysis* 9, no. 1: 1–44. https://doi.org/10.21642/JGEA.090101AF.

Briguglio, M. 2021. "Taxing Household Waste: Intended and Unintended Consequences." *Journal of Cleaner Production* 304: 127034. https://doi.org/10.1016/j.jclepro.2021.127034.

Britz, W., H. Dudu, and E. Ferrari. 2014. "Economy-Wide Impacts of Food Waste Reduction: A General Equilibrium Approach." EAAE 2014 Congress, Slovenia.

Caldeira, C., V. De Laurentiis, A. Ghose, S. Corrado, and S. Sala. 2021. "Grown and Thrown: Exploring Approaches to Estimate Food Waste in EU Countries." *Resources, Conservation and Recycling* 168: 105426. https://doi.org/10.1016/j.resconrec.2021.105426.

Carattini, S., A. Baranzini, and R. Lalive. 2018. "Is Taxing Waste a Waste of Time? Evidence From a Supreme Court Decision." *Ecological Economics* 148: 131–151. https://doi.org/10.1016/j.ecolecon.2018.02.001.

Casonato, C., L. García-Herrero, C. Caldeira, and S. Sala. 2023. "What a Waste! Evidence of Consumer Food Waste Prevention and Its Effectiveness." *Sustainable Production and Consumption* 41: 305–319. https://doi.org/10.1016/j.spc.2023.08.002.

Cattaneo, A., M. V. Sánchez, M. Torero, and R. Vos. 2021. "Reducing Food Loss and Waste: Five Challenges for Policy and Research." *Food Policy* 98: 101974.

Corong, E. L., T. W. Hertel, R. McDougall, M. E. Tsigas, and D. van der Mensbrugghe. 2017. "The Standard GTAP Model, Version 7." *Journal of Global Economic Analysis* 1: 1–119.

De Laurentiis, V., C. Patinha Caldeira, F. Biganzoli, and S. Sala. 2021. *Building a Balancing System for Food Waste Accounting at National Level (EUR 30685 EN)*. Publications Office of the European Union. https://doi.org/10.2760/1669.

European Commission. 2019. "Commission Delegated Regulation (EU) 2019/1597." https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019D1597.

European Commission. 2022. "Safeguarding Food Security and Reinforcing the Resilience of Food Systems." Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. https://agriculture.ec.europa.eu/document/download/b919a076-a14e-4180-a963-5216afcf02ea_en.

European Commission. 2023. "Proposal for a Directive of the European Parliament and of the Council Amending Directive 2008/98/EC on Waste." https://eur-lex.europa.eu/resource.html?uri=cellar:05b634bd-1b4e-11ee-806b-01aa75ed71a1.0001.02/DOC_1&format=PDF.

European Commission. 2024. "Strategic Dialogue on the Future of EU Agriculture: A Shared Prospect for Farming and Food in Europe." https://agriculture.ec.europa.eu/document/download/171329ff-0f50-4fa5-946f-aea11032172e_en?filename=strategic-dialogue-report-2024_en.pdf.

European Commission. 2025. "A Vision for Agriculture and Food Shaping Together an Attractive Farming and Agri-Food Sector for

Future Generation." eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52025DC0075.

European Council. 2024a. "Strategic Agenda 2024–2029." sn02167en24_web.pdf.

European Council. 2024b. "Environment Council, 17 June 2024: Main Results." Environment Council – Consilium.

European Council. 2024c. "Waste Framework Directive: Council Set to Start Talks on Its Revision." Consilium.

European Council. 2025a. "Council and Parliament Agree to Reduce Food Waste and Set New Rules on Waste Textile." Consilium.

European Council. 2025b. "Revision of the EU Waste Framework Directive - Textiles and Food Waste." Carriages Preview | Legislative Train Schedule.

European Court of Auditors. 2024. "Special Report 20/2024: Common Agricultural Policy Plans – Greener, but Not Matching the EU's Ambitions for the Climate and the Environment (No. C/2024/5766)." http://data.europa.eu/eli/C/2024/5766/oj.

European Parliament. 2024a. "Revision of the EU Waste Framework Directive - Textiles and Food Waste." Carriages preview | Legislative Train Schedule.

European Parliament. 2024b. "Textiles and Food Waste Reduction: New EU Rules to Support Circular Economy | News | European Parliament."

European Parliament. 2024c. "MEPs Call for Tougher EU Rules to Reduce Textiles and Food Waste | News | European Parliament."

Eurostat (ESTAT). 2022. *Food Waste and Food Waste Prevention by NACE Rev. 2 Activity - Tonnes of Fresh Mass*. European Commission. https://ec.europa.eu/eurostat/databrowser/view/ENV_WASFW/default/table?lang=en&category=env.env_was.env_wasst.

Eurostat (ESTAT). 2023. *Food Waste and Food Waste Prevention by NACE Rev. 2 Activity - Tonnes of Fresh Mass*. European Commission. https://ec.europa.eu/eurostat/databrowser/view/ENV_WASFW/default/table?lang=en&category=env.env_was.env_wasst.

Fabi, C., F. Cachia, P. Conforti, A. English, and J. R. Moncayo. 2021. "Improving Data on Food Losses and Waste." *Food Policy* 98: 101934.

Food and Agriculture Organization of the United Nations. 2011. *Global Food Losses and Food Waste - Extent. Causes and Prevention*. Food and Agriculture Organization.

Food and Agriculture Organization of the United Nations. 2019a. *The State of Food and Agriculture 2019: Moving Forward on Food Loss and Waste Reduction*. UN.

Food and Agriculture Organization of the United Nations. 2019b. "Food Loss and Waste Database." http://www.fao.org/food-loss-and-food-waste/flw-data/en/.

Gatto, A., M. Kuiper, and H. van Meijl. 2023. "Economic, Social and Environmental Spillovers Decrease the Benefits of a Global Dietary Shift." *Nature Food* 4: 496–507. https://doi.org/10.1038/s43016-023-00769-y.

Gille, Z. 2012. "From Risk to Waste: Global Food Waste Regimes." *Sociological Review* 60, no. S1: 27–46. https://doi.org/10.1111/1467-954X.12036.

Hegwood, M., M. G. Burgess, E. M. Costigliolo, et al. 2023. "Rebound Effects Could Offset More Than Half of Avoided Food Loss and Waste." *Nature Food* 4: 585–595. https://doi.org/10.1038/s43016-023-00792-z.

Hoehn, D., I. Vázquez-Rowe, R. Kahhat, et al. 2023. "A Critical Review on Food Loss and Waste Quantification Approaches: Is There a Need to Develop Alternatives Beyond the Currently Widespread Pathways?" *Resources, Conservation and Recycling* 188: 106671. https://doi.org/10.1016/j.resconrec.2022.106671.

Hoornweg, D., and P. Bhada-Tata. 2012. "What a Waste: A Global Review of Solid Waste Management." In *Urban Development Series, Knowledge Papers No. 15*. World Bank. http://hdl.handle.net/10986/17388.

Keramidas, K., F. Fossè, A. Díaz-Vázquez, et al. 2021. *Global Energy and Climate Outlook 2020: A New Normal Beyond Covid-19*. Publications Office of the European Union. https://doi.org/10.2760/608429.

Kuiper, M., and H. D. Cui. 2021. "Using Food Loss Reduction to Reach Food Security and Environmental Objectives—A Search for Promising Leverage Points." *Food Policy* 98: 101915.

Laborde, D., W. Martin, J. Swinnen, and R. Vos. 2020. "COVID-19 Risks to Global Food Security." *Science* 369, no. 6503: 500–502. https://doi.org/10.1126/science.abc4765.

Latka, C., A. Parodi, O. van Hal, et al. 2022. "Competing for Food Waste—Policies' Market Feedbacks Imply Sustainability Tradeoffs." *Resources, Conservation and Recycling* 186: 106545.

Lusk, J. L., and B. Ellison. 2017. "A Note on Modelling Household Food Waste Behaviour." *Applied Economics Letters* 24, no. 16: 1199–1202. https://doi.org/10.1080/13504851.2016.1265070.

Nenert, C., D. González, C. Giner, and S. Hubertus Gay. 2025. "The Potential Effects of Reducing Food Loss and Waste: Impacts on the Triple Challenge and Cost-Benefits Analysis." In *OECD Food, Agriculture and Fisheries Papers, No. 222*. OECD Publishing. https://doi.org/10.1787/bd2aedc6-en.

Philippidis, G., M. Sartori, E. Ferrari, and R. M'barek. 2019. "Waste Not, Want Not: A Bioeconomic Assessment of Household Food Waste Reductions in the EU." *Resources, Conservation and Recycling* 146: 514–522.

Porter, S. D., D. S. Reay, E. Bomberg, and P. Higgins. 2018. "Avoidable Food Losses and Associated Production-Phase Greenhouse Gas Emissions Arising From Application of Cosmetic Standards to Fresh Fruit and Vegetables in Europe and the UK." *Journal of Cleaner Production* 201, no. 10: 869–878. https://doi.org/10.1016/j.jclepro.2018.08.079.

Rutten, M., and A. Kavallari. 2016. "Reducing Food Losses to Protect Domestic Food Security in the Middle East and North Africa." *African Journal of Agricultural and Resource Economics* 11, no. 2: 118–130. http://afjare.org/wp-content/uploads/2018/02/3-Rutten-Kavallari.pdf.

Rutten, M., P. Nowicki, M. J. Bogaardt, and L. Aramyan. 2013. *Reducing Food Waste by Households and in Retail in the EU: A Prioritisation Using Economic, Land Use and Food Security Impacts*. LEI Wageningen UR. https://edepot.wur.nl/290135.

Schanes, K., K. Dobernig, and B. Gozet. 2018. "Food Waste Matters - A Systematic Review of Household Food Waste Practices and Their Policy Implications." *Journal of Cleaner Production* 182: 978–991. https://doi.org/10.1016/j.jclepro.2018.02.030.

Tselengidis, A., and P. O. Östergren. 2019. "Lobbying Against Sugar Taxation in the European Union: Analysing the Lobbying Arguments and Tactics of Stakeholders in the Food and Drink Industries." *Scandinavian Journal of Public Health* 47, no. 5: 565–575. https://doi.org/10.1177/1403494818787102.

United Nations Environment Programme (UNEP). 2024. "Food Waste Index Report 2024: Think Eat Save: Tracking Progress to Halve Global Food Waste." https://www.unep.org/resources/publication/food-waste-index-report-2024.

United Nations General Assembly. 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development*. United Nations.

Vanham, D., F. Bouraoui, A. Leip, B. Grizzetti, and G. Bidoglio. 2015. "Lost Water and Nitrogen Resources due to EU Consumer Food Waste." *Environmental Research Letters* 10, no. 8: 84008. https://doi.org/10.1088/1748-9326/10/8/084008.

Vesela, L., A. Králíková, and L. Kubíčková. 2023. "From the Shopping Basket to the Landfill: Drivers of Consumer Food Waste Behaviour." *Waste Management* 169: 157–166. https://doi.org/10.1016/j.wasman.2023.07.002.

Woltjer, G. B., and M. H. Kuiper. 2014. "The MAGNET Model: Module Description (LEI Report 14–057)." Wageningen University & Research. https://edepot.wur.nl/310764.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** Supporting Information.