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Article

The Economic and Welfare Effects of Food Waste Reduction on a Food-Production-Driven Rural Region

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Abstract: Food waste is economically and ecologically unsustainable; the benefits of food waste reduction are indisputable. Yet knowledge of the economic trade-offs and knock-on effects of such reduction is deficient. This study examines the economic effects of food waste reduction in a rural region that is a nationally important producer of agricultural and food products in Finland. We built a detailed social accounting matrix to trace the transactions among the economic agents. Five different simulations of food waste reduction were run by applying a computable general equilibrium model. In the simulations, households and food services halved their food waste. The results indicated that food waste reduction is economically worthwhile in terms of regional investments and gross domestic product at market prices. However, the reduction induced economic trade-offs and welfare redistribution. The value added to the agriculture and food industries and the welfare of agricultural households decreased, albeit that the simulated compensations alleviated the effects. In the long run, falling agricultural wages and factor incomes entail closedowns and, finally, decrease local food production. This aspect is worth considering in terms of policy planning under the principle of just transition of the European Green Deal.

Keywords: food waste; consumption; computable general equilibrium; food policy; rural economy; agriculture; food services

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1. Introduction

Food waste reduction is among the key sustainability challenges of the food system. It is highlighted in the contexts of population growth, augmenting pressures on the environment, shifting dietary patterns and rising food security concerns [1,2]. Policymakers, activists, international and non-governmental organisations and academia agree that food waste is economically and ecologically unsustainable. Accordingly, the United Nations [3] has acknowledged the reduction of food waste as a high-level policy target and, consequently, it has become a policy objective both at the European Union (EU) level [4–6] and nationally in Finland [7].

Food waste is a globally prevalent phenomenon with multiple reasons for its existence [2,8,9]. Various studies have investigated the magnitude of food waste [10–13], and literature on food waste prevention and reduction focused on the drivers of food waste is burgeoning, e.g., [14,15]. Accordingly, food waste generation is a function of cultural, personal, political, geographic and economic forces that influence behaviour in specific ways, and it may differ from person to person, year to year, or society to society [15]. Several studies have demonstrated that feelings of guilt because of personal concerns, such as financial loss, perceived behavioural control and negative attitudes, may predict the intention to reduce food waste. Yet households often have ambivalent attitudes towards waste prevention and face conflicts between good intentions to reduce food waste and personal preferences regarding food safety, taste and freshness. Socio-demographic factors play less of a predictive role [14].

These studies, however, have provided a limited conceptual understanding of the economics of food waste [16]. The reduction of food waste is recommended, although the understanding of the economic trade-offs the stakeholders face is limited [17]. Rutten [18] concluded that previous studies have justified the unambiguous benefits of food waste reduction with the facts that production costs decrease and producer incomes increase, and correspondingly consumers will benefit because of the lower food prices and increased savings. Yet Britz et al. [19] argue that, once the economic trade-offs are considered, food waste reduction will have distributional effects because the economic changes will cause redistribution of wealth and income among the economic agents.

Regional examination and especially the estimation of the distributional economic effects on a rural, agriculture-dependent economy are lacking in the food waste reduction literature. Such regions often have a key role in national food production and thus on national food security. Further, numeric modelling-based household food waste reduction studies analysing the knock-on effects of the reduction of food waste are infrequent. Hence, in this article, we study the regional economic effects of food waste reduction. Our case study area is South Ostrobothnia (NUTS 3 region) in western Finland. The region is highly dependent on its agro- and bioeconomy, which include strong agriculture, manufacturing, technology, logistics and research [20]. We model the economic effects of food waste reduction such that the focus is on households and food services and the economic trade-offs and knock-on effects. The changes in welfare and income distribution are especially considered.

We build a detailed social accounting matrix to trace the transactions among the economic agents. We run five different simulations of food waste reduction by applying a computable general equilibrium (CGE) model. In the simulations, households and food services halve their food waste. We use the CGE model because it is a well-functioning tool for examining the economy-wide effects of food waste reduction by modelling simultaneously the interdependencies between all the economic sectors, agents and markets in the economy. Consequently, the modelling results show both the direct and indirect effects of food waste reduction. Our approach follows Britz et al. [19,21], Campoy-Muños et al. [22], Philippidis et al. [23] and Rutten et al. [24].

Our results indicate that food waste reductions are economically worthwhile in terms of regional investments and gross domestic product at market prices. However, these reductions induced economic trade-offs and welfare redistribution. Accordingly, food waste reduction did not unambiguously reduce costs and generate savings; the value added to the agriculture and food industries and the welfare of agricultural households decreased, albeit that the simulated compensations alleviated the effects. In the long run, falling agricultural wages and factor incomes entail closedowns and, finally, decrease local food production. This aspect is worth considering in terms of policy planning under the principle of just transition of the European Green Deal.

Literature Review

There are various studies outlining the analytical framework of the economics of food waste. For example, de Menna et al. [25] suggest that life cycle methodologies, and specifically a combined life cycle costing (LCC) and life cycle assessment (LCA) approach, could be appropriate tools for the identification of win–win solutions, maximising environmental impact reduction and economic resource efficiency. Correspondingly, de Menna et al. [26] present a specific framework for food waste practitioners combining LCA and LCC. Moreover, going beyond life cycle approaches, Rutten [18] creates a theoretical framework to analyse the economy-wide impacts of food loss and waste reduction. Katare et al. [27] explore the taxing of food inputs and derive a theorem on social-optimal waste-disposal taxes and government incentives. In addition, Drabik et al. [16] developed a micro foundational model of waste for at-home and away-from-home food consumption, and de Gorter et al. [28] further provide an extension to this by including intermediaries and farmers.

As indicated [14,15], to keep or waste food is not always a straightforward decision for households—nor from the economic perspective. Lusk and Ellison [29] argue that many analyses of food waste seem to conceptualise it as a mistake or inefficiency rather than an economic phenomenon that arises from preferences, incentives and constraints. Consumers and producers have time and other resource constraints, which imply that it might not be worth rescuing every piece of food. Household food waste is a luxury good [30], and the decisions to discard food depend on food prices and income [29,30]. Decisions can vary according to contextual factors: households are less likely to waste leftovers when the meal cost is high, for example [31].

Similarly, Verma et al. [32] suggest that consumer food waste follows a linear-log relationship with consumer affluence and starts to emerge when consumers reach a certain threshold: an approximately $6.70/day/capita level of expenditure. In addition, by extending their method to a time series, Lopez Barrera and Hertel [33] further provide more accurate projections of household food waste and find that the emerging economies, particularly China and South Asia, are likely to play a key role in determining global food waste at mid-century.

Höjgård et al. [34] reason that household food waste could be reduced when raising the price of food by increasing the value added tax of food. Yet Hamilton and Richards [35] underscore that the aggregate effects of food policies on food waste depend critically on the distribution of price elasticities among affected households. Accordingly, under certain circumstances, high food prices and policies that reduce the marginal cost of household food utilisation do not lead to reduction of food waste. For example, high fresh food prices increase food waste for households with sufficiently high rates of food utilisation. Policies that reduce the price of fresh food also increase food waste for households with inelastic food demand and decrease food waste among households with high price elastic demand for fresh food. Moreover, food waste makes household demand for fresh food more price elastic, and thus, when the demand is sufficiently price elastic, policies designed to reduce the marginal cost of food utilisation (e.g., by means of facilitating meal planning and/or providing clear labelling information) can increase the quantity of fresh food purchases. As a result, food waste increases because of increased food purchases.

There are several studies analysing the economy-wide effects of food waste reduction by using partial and general equilibrium models. For example, the OECD [36] study provides estimates of market and trade impacts of food loss and waste reduction. Their results reveal the trade-offs: when consumers save money by reducing food waste, the agricultural producer will lose sales due to reduced prices and quantity. Correspondingly, Britz et al. [21], Philippidis et al. [23] and Rutten et al. [24] argue that attempts to reduce food waste might cause severe losses for the agriculture and food production sectors. Furthermore, Britz et al. [19,21] point out that costs play a key role in determining the final impact of food waste reduction. In addition, Rutten et al. [24] indicate that, in terms of gross domestic product (GDP), it would be less costly to encourage households to pursue a transition towards a healthy diet rather than to encourage households to waste less food. Given that the results also suggest a decrease in rural employment and wages, in terms of food security the benefit of food waste reduction may only be true for urban households. Yet Campoy-Muños et al. [22] highlight that the structure of the economy wherein the reduction is implemented determines the final impact.

Policy-wise, awareness raising campaigns are the dominant policy measure deployed on a regional, national and European level [14]. Interestingly, consumer education campaigns to promote waste-reduction behaviours have been found to be one of the most cost-effective option. However, the overall effectiveness of these campaigns is uncertain because of the complex and varying reasons for consumer food waste [37].

Lastly, actions aiming to reduce food waste may conflict with other policy objectives such as protection of the environment or promotion of a healthy diet [34]. For example, by using a combined LCC and LCA approach, Martinez-Sanches et al. [38] conclude that food waste prevention, while proving the highest welfare gains, as more services/goods could be consumed with the same income, could incur the highest environmental impacts if the monetary savings from unpurchased food commodities were spent on good/services whose production has larger environmental impacts than those of the prevented food.

2. Materials and Methods

The study is based on the standard economic theory of general equilibrium. The general equilibrium theory describes the functioning and properties of market economies. It describes the economy as a collection of economic agents who make supply and demand decisions regarding commodities, labour factors and assets to enhance their own economic interests and profits [39]. The first basic principle of the theory is based on the Walrasian theory of market behaviour. According to basic Walrasian conjecture, the laissez-faire operation of the price mechanism, in an environment of deregulated competitive markets where agents are motivated by self-interest, will produce coherence in the sense of market-clearing optimal outcomes [39]. In the equilibrium, market prices are solved such that the required equilibrium conditions will hold; demand equals supply for all commodities, and in the constant-returns-to-scale case, zero-profit conditions are satisfied for each industry [40]. According to Arrow and Debreu [41], the equilibrium does not only clear markets but also achieves an efficient resource allocation. Therefore, the relation between the equilibrium—a competitive equilibrium as Arrow and Debreu have stated—and the problem posing of normative and welfare economics is equally important. Under suitable assumptions of consumer preference and the production possibilities of producers, the resource allocation in a competitive equilibrium is optimal in the sense of the Pareto principle.

Because of its ability to reveal indirect economic linkages and underlying structural relations, Devarajan and Robinson [42] feature the CGE framework as an illustrative tool for analysing economic shocks and different policies. Criticism often focuses on the fact that the results attained from the CGE models are not econometrically estimated and therefore cannot be subjected to the usual forecasting tests. According to Hertell [43], however, the CGE model results are reliable on condition that (i) the individual components of the system are based on plausible, perhaps even econometrically estimated, relationships, (ii) the underlying social accounting matrix (SAM) is accurate and reflects the best economy-wide data available and (iii) the equilibrium assumptions and the macro-closures are plausible.

2.1. Computable General Equilibrium Model

For empirical analysis, we apply the standard stationary general equilibrium model designed by Lofgren et al. [44] for the International Food Policy Research Institute (IFPRI). All the model equations and illustrative figures detailing its structure are provided in the publication [44].

Currently, dynamic modelling is widely applied for regional analysis (see, for example, Partridge & Rickman [45]). Dynamics enables the modelling of capital accumulation, technical changes and long-term policy scenarios. More advanced models and techniques, for example dynamic stochastic general equilibrium (DSGE) models (see, for example, Rickman [46]) have been developed. At their best, these models combine the best qualities of partial equilibrium models and CGE models. Yet there is a trade-off between the clarity of the causal mechanisms and additional model features. Accordingly, along with the increasing complexity, danger of the so-called black box syndrome grows. By contrast, simple models, despite their undeniable deficiencies, might be more useful for interpreting and comparing different policy outcomes [42].

The IFPRI model is open code and was solved with GAMS software. The model includes a set of linear and nonlinear simultaneous equations that determine the behaviour of the economic agents in the model. The CGE model is linked to a file for country- or region-specific data that are structured as a SAM. In this study, the SAM represents the economy of the South Ostrobothnia region.

Löfgen et al. [44] detail model features, essential for this article, as follows. At the bottom level, where value added is formed, the primary factor, i.e., the labour and capital mix, is determined by a constant elasticity of substitution (CES) function. For each activity, the demand for disaggregated intermediate inputs is determined by the Leontief formulation. The institutions in the model are households, enterprises, the government and the rest of the world. Households receive factor income (directly or indirectly via the enterprises) and transfers from other institutions, such as government income transfers. Households use their income for consumption, savings, taxes and transfers to other institutions. Household consumption is allocated across different commodities according to the linear expenditure system (LES) demand functions that are derived from the maximisation of a Stone-Geary utility function. The spending on individual commodities is a linear function of total consumption spending. Domestic aggregated output is generated from the outputs of the activities producing a given commodity. A CES function is used for aggregation. An optimisation problem sets the demand for the output of each activity. Activity-specific commodity prices serve to clear the implicit market for each disaggregated commodity. The aggregated output is then allocated between exports and domestic sales. Suppliers maximise sales revenue subject to imperfect transformability between exports and domestic sales, as expressed by a constant elasticity of transformation (CET) function.

It is necessary to estimate two groups of parameters for the CGE models [42]. The first group is share parameters, for example intermediate input costs, average tax rates, consumer expenditure shares and import and export shares. These endogenous parameters are calculated by using the information in the base year SAM. The second group consists of elasticity parameters that describe the curvature of structural functions. For example, the CES function requires specification of the elasticities. The elasticities presented in the Supplementary Materials (Table S4) were drawn from different sources. The production elasticities, except the output aggregation elasticity that was drawn from the model's default, are based on previous Finnish research [47], and the household income elasticities are based on information from the US Economic Research Service [48]. Honkatukia et al. [49] have estimated only a slightly higher value for Finnish agricultural products, and a slightly lower value for food products. The Frisch parameter value was set to −1, implying that all household consumption is discretionary.

Previous studies recommend that values of elasticities of substitution for regional trade should be higher compared with those applied in the international trade studies (see Bilgic et al. [50]). The reasoning is that regions face lower barriers to trade than nations because they are geographically closer to each other [51]. In our study, an overall value of 2 is applied for all the products. This represents a middle range of suggested values. In Finland, Törmä and Lehtonen [52] have applied 4.00 for both Armington elasticity and transformation elasticity.

Since the macroeconomic closures of the model largely determine the model's qualitative characteristics [53], the applied closure rules aim at reflecting the empirical situation of the study region. The government closure is set to leave all tax rates fixed and allow government savings to change. The rationale for this closure is based on the administrative position of the region: in Finland, taxation decisions are made either at the government level or within municipalities—not at the regional level. With regard to external balance, the real exchange rate is fixed (indexed to the model numéraire), whereas foreign savings and the trade balance are flexible. This reflects a situation of a small open economy that faces an infinitely flexible demand. The major share of the imports and exports are from, or go to, other parts of Finland. In addition, the region is dependent on transfers and investments from the rest of Finland. Furthermore, for the Savings-Investment closure, all non-governmental savings rates are fixed and investments will adjust. The consumer price index is flexible in the simulations. As for factor markets, capital, land and labour factors are fully employed. Land is activity specific, while capital and labour are mobile. Neoclassical labour closure is applied, implying that endogenous wages clear the labour markets. The unemployment rate in South Ostrobothnia is below the national figures that argue for this choice.

2.2. Social Accounting Matrix

The SAM is a square matrix where incomes are recorded along the account rows and expenditures along the account columns. The fundamental principle for this double-entry accounting is the requirement that, for each account in the SAM, the total revenue (row total) equals the total expenditure (column total) [44]. The SAM describes the economic structure and transactions of South Ostrobothnia such that enterprises, employees and households are rural-urban separated. The SAM consists of activity and commodity accounts; transaction cost accounts; capital, land and several labour factor accounts; firm and household accounts; government and tax accounts; and imports and exports, investments and savings. It accounts for the transactions with the rest of Finland and the rest of the world.

The basic regional input-output table and trade flows were picked from the data of the Finnish Government Institute for Economic research (VATT) [54]. The structure of this data follows the principles of the TERM model database [55]. Accordingly, Finnish national input–output tables were the starting point for the regional tables. Trade volumes following an inverse power of distance (i.e., the gravity formula) were used to construct trade matrices consistent with pre-determined row and column totals. However, VATT-tables are largely region specific, since Statistics Finland collects region-specific data that was also utilized. The base year of these tables was 2008. Our research required additional, more recent and more disaggregated data on the regional economy and on the rural and urban sub-areas. These data were collected from the databases of Statistics Finland [56–59], the Regional Council of South Ostrobothnia [60] and Natural Resources Institute Finland [61]. In terms of regional GDP level, the input–output table from 2008 is not detrimental, because an economic recession after 2008 lowered Finnish GDP so that the 2008 GDP level was not reached until 2019 [62]. Even if there are minor inaccuracies in the division of the GDP among regional industries between 2008 and the more recent data sources, the same industries remained important [63].

The rural-urban division of the industries was attained by channelling labour and capital incomes to rural and urban households and firms. The division of industries into rural and urban is based on employment statistics along with information from industries and municipalities and on enterprise structures. Labour was divided into rural and urban low-skilled (blue collar) and high-skilled (white collar) labour. In addition, farming and other farm-related activities were separated into its own category. Correspondingly, the shares of the various household types are based on statistics of household dwelling units, household income and expenditures, and employment by age and by region and survey information [64]. The division into rural and urban is based on municipality information. The South Ostrobothnia SAM is shown in the Supplementary Materials (Table S1), and detailed information on household income and household consumption structures are seen correspondingly in Tables S2a,b and S3, respectively. Finally, the SAM was balanced by using the cross-entropy method [65].

2.3. Study Region

The study area is South Ostrobothnia, a region located in the province of western Finland. The region's main industrial clusters are food, metal and technology. In addition, wood and furniture industries are important. The region is highly dependent on its agro- and bioeconomy, which include strong agriculture, manufacturing, technology, logistics and research [20]. This makes South Ostrobothnia an important area for national food security, and a particularly interesting region in which to study the effects of food waste reduction.

There are various agricultural and manufacturing companies in the region. The share of employment in primary production and in manufacturing is higher than in the whole country. In 2019, 7.4% of the employed worked in primary production, 17.9% in manufacturing and 74.7% in services. Nationally, only 2.7% of the employed worked in primary production and 12.5% in manufacturing, as services covered 84.8% of the employed.

In addition, crop and animal production, hunting and related services covered 34.3% of all establishments in South Ostrobothnia [56,66].

South Ostrobothnia is divided into 18 municipalities and in 2020 the region had 192,150 inhabitants. Almost 70% of the population lives in rural areas. The regional centre, the urban area of our study, is Seinäjoki with 64,130 inhabitants. Even if the level of education in South Ostrobothnia is below the Finnish average, over half of the employed workforce holds an upper secondary degree [56,57].

Most of the workforce consists of lower-level employees and manual workers. The employment rate in South Ostrobothnia was 76% in 2020 and the unemployment rate 5.6%. In addition, household disposable income in South Ostrobothnia was 20,548 euros per capita, which was 2100 euros less than in the whole country. Lastly, as indicated in Figure 1, the regional per capita GDP was 32,655 euros in 2019, while the national figure was 41,632 euros [58,67].

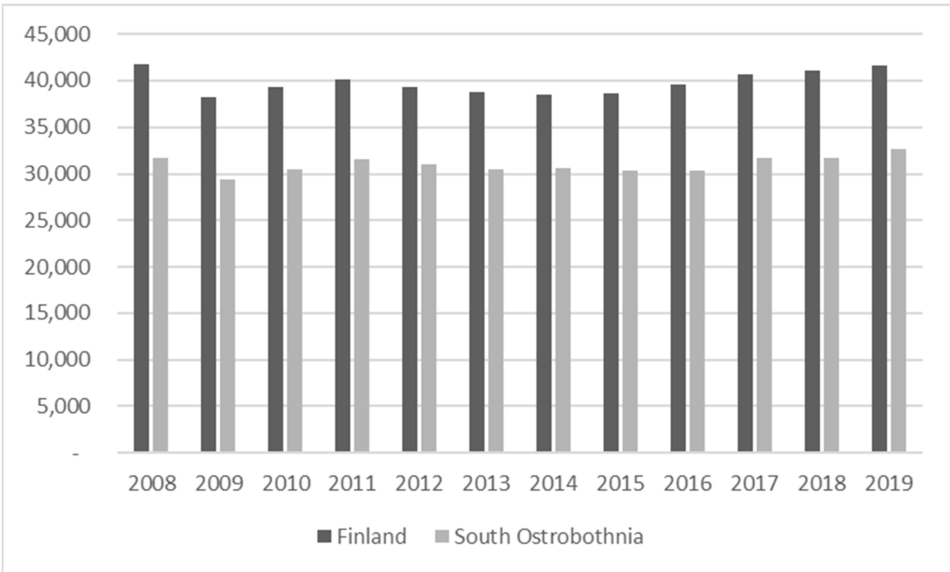

Figure 1. Gross domestic product (GDP) per capita, reference year 2015, euros [58].

2.4. Amount of Food Waste

In the EU alone, approximately 88 million tons of food was wasted in 2010, corresponding to 179 kg per capita per year [12]. However, the differences among the member states were significant. The annual food waste in the EU ranged from 50 kg per capita in Greece to 180 kg per capita in the Netherlands. Households produce the major share of food waste. Stenmark et al. [13] estimated that the food waste from food services is 130 million kg and in households 345 million kg per year. Yet, as illustrated in Figure 2, the Natural Resources Institute Finland's estimates range from 425 million to 535 million kg of food loss and waste. This includes 75 million to 85 million kg of food service waste and 120 million to 160 million kg of household waste [68]. The total amount corresponds to approximately 76 kg to 96 kg per capita per year in Finland.

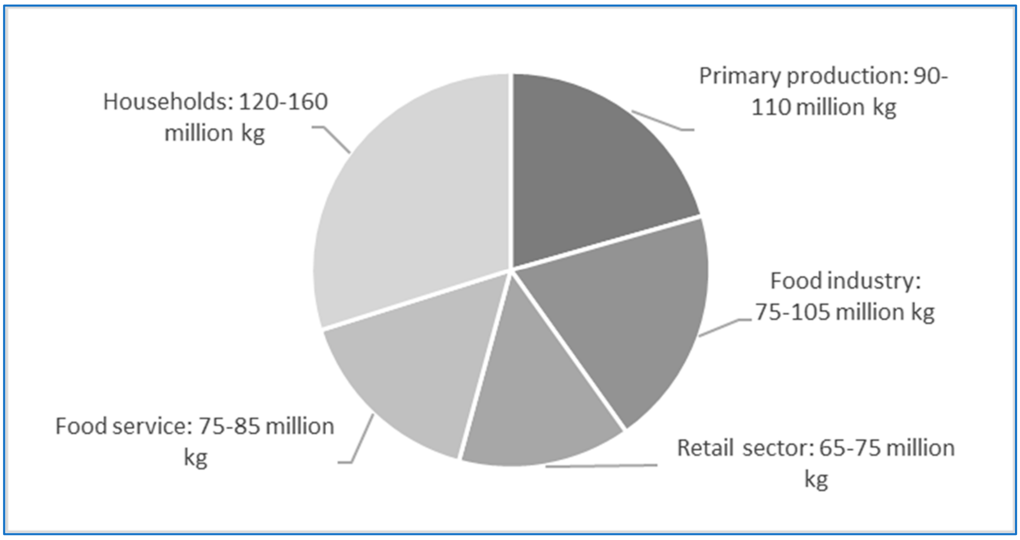

Figure 2. Food loss and waste in Finland [68].

2.5. Food Waste Reduction Simulations

Our simulations will demonstrate that food waste reduction does not unambiguously reduce costs and generate savings. Once the economic trade-offs are considered, food waste reduction will have distributional effects because the economic changes will cause redistribution of wealth and income among the economic agents [19]. Furthermore, it is evident that the reduction of food waste in food services and households is not cost-free; the food industry, agriculture and households closely connected to these are likely to carry the heaviest burden of the effects of food waste reduction, e.g., [21,23,24,36].

The analysis includes five different simulations. The simulations force food services and/or households to halve their existing food waste. This target is aligned with United Nations Sustainable Development Goal 12.3, which aims to halve food waste at retail and consumer levels by 2030 [3] and, thus, also with the policy objective at the EU level [4–6] and nationally in Finland [7].

Our data—the SAM—do not include specific information on existing food waste. Yet the SAM describes the economic structure and transactions of South Ostrobothnia during a single accounting period. Hence, it includes data on the actual consumption and production—information crucial to our simulations. Therefore, we assume that, in the starting situation, the existing market equilibrium also includes food waste [21].

We use the estimates of Katajajuuri et al. [11] to calculate the size of shocks. Accordingly, household waste was 23–30 kg of food per person per year. As indicated in Table 1, this corresponds to approximately 5% of total food consumption. In food services, the total amount of food waste is approximately 75–85 million kg per year, which corresponds to 8–27% of cooked food, depending on the type of restaurant. Fast food restaurants cause the least food waste, whereas in municipal food services one-third of the cooked food ends up as food waste. Consequently, in restaurants and hotels, the amount of food waste equals around 19% of cooked food, in day-care centres roughly 27%, in retirement and children's homes and in hospitals 26% and in schools 18%.

Scenario 1—'food services'—simulates food waste reduction in food services. The simulation includes food services produced by hotels and restaurants, the education sector and the health and social service sector. The education sector and health and social service sector are included to cover food services produced in day-care centres, retirement homes, children's homes and hospitals. The reduction of food waste is performed by cutting the use of agricultural commodities and food products as intermediate inputs. Thus, the simulation introduces a shock to the use of intermediate inputs ($ica_{c\ a}$). The size of the shock is set to a level at which each of the sectors concerned reduces the use of agricultural commodities and food products as intermediate inputs corresponding to the target level of the reduction. Hence, the hotel and restaurant sector decrease the use of the food items by 15%, the education sector by 9% and the health and social service sector by 13.25%.

Table 1. Base values and target levels of simulations.

	Amount of Food Waste [1]	Starting Value [2]	Target Level	Scenario
Food services, total	75–85 M kg			
Hotels and restaurants		19%	9%	1,4
Education		18%	9%	1,4
Health and social services		26.5%	13.25%	1,4
Households	120–160 M kg	5%	2.5%	2,3,4,5

[1] Finland, total. [2] Share of food waste: the share of cooked food in food services, and the share of total consumption of food items of households.

The 'food services' simulation corresponds to the 'free lunch' scenario in the study by Britz et al. [21], where the activity in question does not bear the costs of the reduction. Consequently, we can assume that food services will become more competitive in the region, but the effect on, for example, the food industry and agriculture is expected to be negative. Food services represent a production sector that prepares ready-to-eat food for sale to individuals and communities. It uses food items as inputs, and thus reducing the use of food products and agricultural commodities decreases the overall demand for these products. The importance of the scenario is to show that, although the simulations do not include the full costs of the reduction, the reduction of food waste is not cost-free.

Scenario 2—'household food waste'—simulates household food waste reduction from at-home food consumption. In the starting situation, we assume that the existing food waste is a result of households buying more food than needed, e.g., [27,35,69], and thus, household food waste reduction can be achieved by decreasing the consumption of food products. As the decisions to discard food depend on food prices and income [29,30], household behaviour can be modified by raising the price of food [34]. Therefore, technically, the effects of household food waste reduction are analysed by levying an extra sales tax (rate of sales tax (tq_c)) on all processed food products. The aim of the scenario is not, however, to analyse the effect of a tax per se; rather, the tax increase is a tool for achieving the target level of household food waste reduction. Nevertheless, the tax increase is expected to increase market prices and reduce the household demand for processed food products [34,70].

To find a level that would result in an approximately 2.5% reduction in households' food product consumption, we multiplied the rate of sales tax by 1.7 to achieve the target level of reduction. As indicated in our results in Section 3, this increases the price of food products by 6.6%. Thus, in this scenario, households will carry the cost of food waste reduction in the form of increased food prices.

Because of the tax effect, we expect the simulation to cause negative welfare effects on all households but especially on agricultural households [24]. Therefore, Scenario 3 introduces a government compensation for households. The 'compensation' simulation is calculated relative to the share of the consumption of processed food in each household group and is modelled by introducing an additional government transfer payment $(trnsfr_{i,\ gov})$. The calculation is based on the results of Scenario 2. Accordingly, to set the level of compensation, we divided the quantity of consumed food products of each household with the quantity of composite supply of food product: $QH_{food\ product\ h} \div QQ_{food\ product}$. Thus, the significance of the scenario is to investigate if such compensation would be sufficient to overcome the negative welfare effects. The fourth scenario—'combined effect'—combines the 'food services' and 'compensation' scenarios.

Finally, for comparison, household food waste reduction is analysed by modifying the households' consumption structures ('food consumption' scenario). The effects are modelled by modifying the marginal share of household consumption of marketed commodity c $(betam_{c,\ h})$. Accurately, we decrease each household group's budget share of food products and allocate the corresponding euro amount to the increased consumption of hotel and restaurant services. Accordingly, the total consumption budget remains equal for all the household simulations, but the tax-induced consequences are refrained. It is worth noting that each household group has individual budget shares of commodities, and for each household group the reduction of food waste is comparable in all the household scenarios.

The scenarios are as follows:

- Scenario 1, food services: 50% reduction in food service food waste by forcing the hotel and restaurant industry, education sector and health and social service sector to reduce the quantity of intermediate demand for agricultural commodities and processed food products.
- Scenario 2, household food waste: 50% reduction in household food waste by introducing an increase on sales tax on all processed food products.
- Scenario 3, compensation: 50% reduction of household food waste by introducing an increase on sales tax on processed food products and a compensation on all households.
- Scenario 4, combined effect: combination of Scenarios 1 and 3.
- Scenario 5, food consumption: 50% reduction of household food waste by decreasing consumption of processed food products and simultaneously increasing consumption of hotel and restaurant services.

The key model equations related to the scenarios are presented in the Supplementary Materials (Figure S1).

3. Results

The following tables summarise the main results of all the scenarios. The economic impacts derived from the simulations are given as a percentage of change over the baseline data encompassed in the corresponding SAM. Table 2 summarises the macroeconomic effects. Accordingly, reduction of food waste in 'food services' increased total absorption, private consumption, imports and investments, while the effect on exports was negative. The GDP at market prices increased by 0.27%.

Table 2. Macroeconomic indicators, real terms, percentage change.

	BASE M EUR	Scenario1 [1]	Scenario2 [2]	Scenario3 [3]	Scenario4 [4]	Scenario5 [5]
Total absorption	5494	0.9%	0.74%	0.71%	1.65%	0.28%
Private consumption	3138	0.19%	−1.15%	−0.22%	−0.02%	0.01%
Investments	1238	3.49%	6.17%	3.69%	7.37%	1.23%
Exports	4031	−0.58%	−0.96%	−1.03%	−1.64%	−0.25%
Imports	4417	0.22%	−0.34%	−0.42%	−0.17%	0.04%
GDP at market prices	5378	0.27%	0.26%	0.24%	0.51%	0.06%
GDP at factor costs	4780	0.0%	−0.01%	−0.01%	−0.01%	0.00%

[1] Scenario1 = Food services; [2] Scenario2 = Household food waste; [3] Scenario3 = Compensation; [4] Scenario4 = Combined effect; [5] Scenario5 = Food consumption.

Scenario 2, 'household food waste', decreased private consumption and exports. Interestingly, investments increased by 6.2%. In addition to investments, total absorption and GDP at market prices increased. The effects of 'compensation' were somewhat similar, while 'combined effect' generated greater economic gains. For example, GDP at market prices increased by 0.5%. The overall economic effects of Scenario 5, 'food consumption', were modest. Total absorption, imports and investments increased, while exports decreased. The GDP rise was 0.06%.

At the activity level (Table 3), the results suggest a significant decrease in the value added of agriculture and the food industry as well as in the imports and exports of agricultural commodities and food products. Accordingly, 'household food waste' decreased the aggregate value added—as well as the level of domestic activity—by 5% in agriculture and by 11% in the food industry. Furthermore, agricultural commodity imports decreased by 11.6% and exports by 1.9%. For food products, imports decreased by 3.2% and exports by 13%.

Table 3. Sectoral changes, percent change.

	Scenario1 [1]	**Scenario2** [2]	**Scenario3** [3]	**Scenario4** [4]	**Scenario5** [5]
Value added:					
Agriculture	−0.44%	−5.11%	−5.15%	−5.60%	−0.33%
Food industry	−0.91%	−11.06%	−10.92%	−11.75%	−1.09%
Hotel and restaurant services	7.45%	−3.26%	−2.38%	5.20%	5.76%
Imports:					
Agric. commodities	−1.01%	−11.59%	−11.36%	−12.26%	−1.16%
Food products	−0.91%	−3.23%	−2.90%	−3.78%	−1.86%
Exports:					
Agric. commodities	−0.18%	−1.91%	−2.08%	−2.31%	0.06%
Food products	−0.92%	−13.05%	−12.95%	−13.79%	−0.88%

[1] Scenario1 = Food services; [2] Scenario2 = Household food waste; [3] Scenario3 = Compensation; [4] Scenario4 = Combined effect; [5] Scenario5 = Food consumption.

The effects of 'food services' on agriculture and the food industry were modest but negative. Yet, as expected, food waste reduction in food services was beneficial, especially for the sector itself. The value added of the hotel and restaurant sector increased by 7.5%, for example. Furthermore, the change in the food consumption structure showed parallel results to those of the 'food services' scenario. The decrease of value added in agriculture and the food industry, for example, was moderate. Because the simulation forced households to increase consumption of hotel and restaurant services, those sectors gained.

For the other sectors of the economy, household food waste reduction had generally positive effects. Interestingly, this applies especially to the other important sectors in South Ostrobothnia: the metal industry, manufacturing of electrical and electronic products and construction. Regarding 'food services' and 'food consumption', the effects on the other sectors were generally modest.

3.1. Effects on Factor Incomes, Factor Demand and Food-Related Prices

Table 4 lists the changes in factor incomes. Capital incomes decreased in each scenario. Agricultural land incomes decreased by 1.2% because of food services' food waste reduction and over 14% because of household food waste reduction, and the change in the consumption structure decreased the land income by 0.9%. All scenarios induced positive wage effects for both rural and urban labour, except for farmers.

Table 4. Effects on factor incomes, percentage change.

	Scenario1 [1]	**Scenario2** [2]	**Scenario3** [3]	**Scenario4** [4]	**Scenario5** [5]
Capital, all sectors	−0.00%	−1.16%	−1.02%	−1.02%	−0.04%
Land, agriculture	−1.19%	−14.07%	−14.03%	−15.11%	−0.93%
Labour:					
Rural skilled	0.14%	0.24%	0.22%	0.36%	0.02%
Urban skilled	0.21%	0.24%	0.24%	0.46%	0.05%
Farmers (agriculture)	−1.19%	−14.07%	−14.03%	−15.11%	−0.93%
Farmers (other farm activities)	0.09%	0.21%	0.17%	0.27%	0.04%
Rural low skilled	0.25%	0.23%	0.03%	0.28%	0.09%
Urban low skilled	0.45%	0.24%	0.07%	0.51%	0.17%

[1] Scenario1 = Food services; [2] Scenario2 = Household food waste; [3] Scenario3 = Compensation; [4] Scenario4 = Combined effect; [5] Scenario5 = Food consumption.

Activity-specific factor demand changed such that capital and labour moved particularly from agriculture and the food industry to other important industries of the region: to the metal industry, manufacturing of electrical and electronic products and construction. For example, capital demand from the metal industry increased by almost 6% and labour demand by approximately 5% because of 'household food waste'. The effects of 'food services' and 'food consumption' on the metal industry were moderate but negative.

'Food services' increased capital demand especially in hotel and restaurant services (7.6%). Similarly, capital demand of hotel and restaurant services increased by 5.8% because of 'food consumption'. Conversely, 'household food waste' and 'compensation' decreased hotel and restaurant services' demand for capital by 2.7% and 1.9%, respectively. Furthermore, capital demand in agriculture (−6.7%) and in the food industry (−10.4%) decreased significantly.

The labour demand of hotels and restaurants increased by 7.5% because of 'food services' and 5.8% because of 'food consumption'. The effects on agriculture and the food industry were negative but modest, while 'household food waste' and 'compensation' decreased labour demand substantially—in the food industry by approximately 11% and in agriculture by approximately 7%.

Household food waste reduction—with and without compensation—decreased the producer price and consumer price of agricultural commodities by 1.3%. For food products, conversely, household food waste reduction increased the producer price by 1.2% and consumer price by 6.6%. Moreover, the value-added price of agriculture decreased by 4.5% and the food industry by 0.3%. The effects of 'food services' and 'food consumption' on food prices were modest, however. 'Food services' decreased the hotel and restaurant producer price by 4% and the consumer price by 2.9%.

3.2. Effects on Household Income and Welfare

The effects on household incomes (Table 5) varied, although in all simulations the income effect on agricultural households was negative. 'Household food waste' decreased the incomes of agricultural households by 2.9%. 'Compensation' partially alleviated the negative effect on agricultural households: the amount of the compensation was adequate to cover income losses caused by the decrease in wages but not the decreased capital and land incomes. As a result of 'food services' and 'food consumption', the effects were negative but modest. As for other than agricultural households, 'food services' and 'food consumption' caused a negative income effect on non-working households. By contrast, 'household food waste' generated positive income effects on non-working households and negative income effects on working households both in rural and urban areas. Nevertheless, the compensation fully alleviated the negative effect.

Table 5. Effects on household income, percentage change.

	BASE M EUR	Scenario1 [1]	Scenario2 [2]	Scenario3 [3]	Scenario4 [4]	Scenario5 [5]
Agricultural HHs	436	−0.19	−2.88	−1.60	−1.77	−0.17
Rural working HHs	1222	0.12	−0.09	0.64	0.76	0.02
Rural other HHs	803	−0.10	0.07	1.44	1.34	−0.03
Rural commuter HHs	187	0.22	−0.05	0.59	0.82	0.07
Urban working HHs	1077	0.19	−0.09	0.66	0.86	0.05
Urban other HHs	351	−0.08	0.08	1.25	1.16	−0.02

[1] Scenario1 = Food services; [2] Scenario2 = Household food waste; [3] Scenario3 = Compensation; [4] Scenario4 = Combined effect; [5] Scenario5 = Food consumption.

In terms of welfare effects, Table 6 shows the values of compensating variation that indicate the amount of money required to bring a household back to the original utility level after the simulations. The 'food services' scenario made agricultural households worse off by 420,000 euros, while the welfare of all the other households increased. For example, rural working households would be willing to pay 2.38 million euros and urban working households 2.69 million euros to obtain the increased welfare.

Table 6. Compensating variation, EUR millions.

	Scenario1 [1]	Scenario2 [2]	Scenario3 [3]	Scenario4 [4]	Scenario5 [5]
Agricultural HHs	−0.42	−13.17	−8.87	−9.22	−0.51
Rural working HHs	2.38	−6.71	−0.66	1.77	0.25
Rural other HHs	0.21	−6.09	3.22	3.42	−0.03
Rural commuter HHs	0.46	−0.85	−0.10	0.37	0.09
Urban working HHs	2.69	−6.02	−0.31	2.46	0.46
Urban other HHs	0.13	−2.25	0.71	0.84	0.00

[1] Scenario1 = Food services; [2] Scenario2 = Household food waste; [3] Scenario3 = Compensation; [4] Scenario4 = Combined effect; [5] Scenario5 = Food consumption.

Household food waste reduction without compensation generated an unambiguously negative welfare impact on all households. The largest negative effect was on agricultural households; the government should compensate agricultural households by 13.3 million euros to restore their original level of welfare. The simulated compensation partially alleviated the negative welfare effects. Only non-working households' welfare increased. Yet the 'combined effect' generated positive welfare effects on all households other than agricultural. The effects of 'food consumption' were moderate. For agricultural households, welfare decreased by 510,000 euros. In addition, the welfare effect was negative for rural non-working households. Other households benefitted from the change in their consumption structure; however, for urban non-working households the welfare effect was non-existent.

3.3. Sensitivity Analysis

A sensitivity analysis tests the robustness of the results. We modified the value of the expenditure elasticity of market demand for food products by households ($LESELAS1(c,h)$). First, we decreased the value of the expenditure elasticity of food products from $LESELAS1(food\ products,h) = 0.4$ to $LESELAS1(food\ products,h) = 0.1$ and then increased to $LESELAS1(food\ products,h) = 2.0$. The value of the elasticity parameters can play an important role in the overall results of the CGE analysis, as the elasticities determine the degree to which agents respond to price changes, e.g., [28]. By decreasing the value of the expenditure elasticity to 0.1, the household demand for the food products becomes almost perfectly inelastic. Accordingly, consumers buy approximately the same amount of food products regardless of the price changes. This is shown in the 'household food waste', 'compensation' and 'food consumption' scenarios because the simulations did not achieve the targeted levels of household food waste reduction. In general, the sensitivity simulations generated parallel results, with slightly greater effects, compared with the simulations presented in Table 2. Household food waste reduction still influenced prices, which further decreased the level of domestic activity of agriculture and the food industry (see Table S5 in Supplementary Materials).

The increase of expenditure elasticity to $LESELAS1(food\ products,h) = 2.0$ made the household demand for the food products elastic (Table S6). As a result, 'household food waste' reduction and 'food consumption' caused notable consumption changes. With elastic household demand for food products, total absorption increased by 1.3% and investments by 8.5% because of 'household food waste'. Furthermore, GDP at market prices increased by 0.36%. For the 'combined effect', GDP increased by 0.59%. In addition, 'food services' and 'food consumption' generated overall positive effects on the economy, increasing GDP by 0.27% and 0.22%, respectively.

4. Discussion

This study examined the economic effects of food waste reduction in a region that is dependent on agriculture and food industries. Furthermore, the focus was on households and food services and on the economic trade-offs and changes in welfare distribution. Our results indicate that the effort to reduce food waste is economically worthwhile for the study region South Ostrobothnia. In terms of GDP at market prices, the results indicated positive effects in all the simulations, and in particular the regional investments increased. The largest gains were attained by decreasing the level of existing food waste simultaneously both in food services and households.

However, the gains were not attained without costs. Especially, agricultural households suffered notable welfare losses, and agriculture and food industries suffered in terms of decreasing value added and capital and land rents. Thus, our results are consistent with previous studies [21,23,24,36], which have demonstrated that the attempts to reduce food waste might cause severe losses for the agriculture and food production sectors. In the long run, decreasing demand and falling factor incomes lead to decreasing supply and business closedowns. This may have considerable impacts on regional and even national food production since South Ostrobothnia accounts for 12% of the value added of the agriculture and food industry in Finland. It is reasonable to presume that the effects would be parallel in other agriculture- and food-industry-driven regions in Europe because of the common markets and common agricultural policy framework. Accordingly, this aspect is worth considering when the European Green Deal is implemented and the principle of just transition is taken into account.

Consistent with Campoy-Muños et al. [22], our results revealed the importance of the region's economic structure. As food services are not among the key industries of the region, changes in their activity had merely a modest effect on the overall economy. Accordingly, food waste reduction in food services was predominantly beneficial for the sector itself. Conversely, household food waste reduction implemented with an increased sales tax on food products led to substantial changes. Hence, in activity level, the economic emphasis moved from the food industry and agriculture to other important industries in the region: to the metal and electronics industries and construction. As a result, the value added and domestic activity of the food industry and agriculture decreased considerably.

Importantly, household food waste reduction implemented via tax increases had effects beyond food consumption. Accordingly, it caused notable negative welfare effects on all household groups and particularly on agricultural households. The simulated compensation alleviated the negative effects only partially. This suggests that food waste reduction does not unambiguously reduce costs and generate savings for households. By contrast, when the corresponding euro amount, saved because of the reduction of household food waste, was reallocated to the purchases of hotel and restaurant services, the overall effects were moderate and parallel with the effects induced by the food waste reduction of food services. Impacts on the regional investments and GDP were, however, positive.

Albeit the significance of food services for the whole regional economy is modest, the food waste reduction of food services considerably affected household incomes and welfare. Reduction of food waste in food services improved the welfare of both rural and urban households, except for agricultural households. Although the welfare effect on agricultural households was negative, it was modest in comparison with the effects of tax-based household food waste reduction. Thus, the results underscore the importance of the varying roles of the different household groups within the economy. Moreover, although the simulations did not contain the full costs of food waste reduction, it is evident that the reduction of food waste in food services and households is not cost-free; in all the scenarios, the food industry, agriculture and households closely connected to these carried the heaviest burden of the effects of food waste reduction.

On the relevance of the simulation choices, we first consider the 'food services' scenario. As expected, the results were in line with theory; when food services reduce the use of inputs, they became more competitive. The decreased market prices benefitted most of the households; agriculture and the food industry, however, suffered. Although the simulation showed positive effects on food services, the approximation of the overall economic effects was limited. First, previous studies [17,19] have concluded that, in comparable simulations, the costs of reduction have not been fully considered. It is likely that reduction of food waste would require, for example, using more labour [19] as minimising service waste calls for better planning and management of the service [71]. Second, and more importantly, there are a number of ways to reduce food waste. The applied simulations do not capture the effects of redistribution of the leftover food, nor if the food would be stored and served again.

Regarding household food waste reduction, the first sets of simulations confirmed the effectiveness of taxes in modifying consumption structures, while the direct manipulation of the consumption structures caused only moderate distributional and indirect economic effects. The restrictions of these simulations correspond to those of the 'food services' scenario. The simulated change in consumption structures does not fully take into account the possible costs of food waste reduction and the fact that there are various possibilities to reduce household food waste. For instance, in our simulations, the targeted level of food waste reduction was achieved by decreasing the household consumption of the food products. In practice, households could still purchase an equal amount of food if the reduction of food waste would be achieved by using more time for meal planning and preparation, e.g., [72]. Nonetheless, this would generate extra costs for the households [73].

From the policy perspective, it is apparent that the ambitious high-level policy target to halve per capita food waste at the consumer level requires actions from everyone—including South Ostrobothnia. Against this setting, as our results suggest, it is important to note that the effects of food waste reduction might vary depending on the execution. Similarly, as the structures of the economies vary, the effects of a specific measure might differ across regions. Any national policy therefore should leave room for area-specific adjustments. Finally, in order to design economically sustainable policy measures, economy-wide effects should be studied carefully. In the future, there is still room for food waste reduction studies globally, nationally and regionally. More information on the costs and economic effects of food waste reduction is called for. Further, because the amount of waste varies between the different food items, disaggregated data would be required to approximate the target levels of food loss and waste reduction more accurately. Further research could assess the interactions of the entire food chain.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su14063632/s1, Table S1: The South Ostrobothnia Social Accounting Matrix. Table S2: Household consumption expenditures. Table S3: Household income. Table S4. Elasticities. Table S5: Sensitivity analysis, macroeconomic indicators, LESELAS1(food products, household) = 0.1. Table S6: Sensitivity analysis, macroeconomic indicators, LESELAS1(food products, household) = 2.0. Figure S1: Equations.

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