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Potential **impacts** on **sub-Saharan Africa** of reducing **food loss** and **waste** in the **European Union**

A focus on food prices and
price transmission effects





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A vendor selling vegetables at a local market
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Fresh food in garbage can to illustrate waste

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Preface

The Save Food Congress of 2011, organized by the Food and Agriculture Organization of the United Nations (FAO) and Messe Düsseldorf GmbH, put the issue of food losses and waste on the political and socio-economic agenda after estimating that almost a third of the food produced for human consumption was either lost or wasted globally. This created the impetus for numerous initiatives to assess the causes and impacts of food losses and waste in order to find feasible and sustainable solutions.

Whereas the prevalence of hunger and food insecurity is often cited as a motivation for reducing losses and waste in agriculture and food systems, the increasing globalized nature of production and consumption has also brought to the fore the need for understanding the potential impacts of such reductions on the wider economy. In particular, it has led to the question of the potential effect of losses and waste on food prices and transmission across regions.

This paper, undertaken jointly by FAO and LEI Wageningen UR, is an attempt to fill the knowledge gap as to the extent to which prices could be impacted and how these effects could be spread across regions, predominantly from industrialized food-importing to developing food-exporting regions, also taking into account price transmission mechanisms. The paper focuses on two regions – the European Union (EU) and sub-Saharan Africa (SSA) – and complements similar work undertaken by other international organizations.

Research took place within the framework of the Global Initiative on Food Loss and Waste Reduction (SAVE FOOD), which FAO coordinates in close collaboration with the International Fund for Agricultural Development (IFAD), World Food Programme (WFP) and United Nations Environment Programme (UNEP). The Global Initiative is a partnership with the public and private sector as well as civil society for: (i) awareness raising; (ii) coherent and effective networking of worldwide efforts; (iii) evidence-based policy, strategy and programme development; and (iv) technical support to programmes and projects.

LEI Wageningen UR is a recognized research institute for agricultural economic modelling and has unique expertise in the area of quantification of economic impacts of food losses and waste reductions.

We sincerely hope that the paper will help to generate informed and evidence-based policy debate on the topic, and encourage countries and regions to consider comprehensively the impacts of food losses and waste generation as well as reduction strategies within and beyond their borders.

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Abstract

This paper investigates, by means of scenario analyses, how reductions in food loss and waste in the European Union (EU) could influence prices in sub-Saharan Africa – as a source and destination of traded agricultural and food products. Four 50 percent reduction scenarios are enacted, using the Modular Applied GeNeral Equilibrium Tool (MAGNET), in addition to a baseline “business as usual” (BaU) scenario. The analysis provides insights on potential impacts in terms of medium- to long-term global and local price changes in sub-Saharan Africa and the mechanisms behind them (changes in production, consumption and trade patterns). It also provides insights in terms of potential welfare impacts.

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Acronyms

AFL	Agricultural food losses
AGS	Rural Infrastructure and Agro-Industries Division
BaU	Business as usual
BCFN	Barilla Center for Food & Nutrition
CFW	Consumption food waste
CGE	Computable general equilibrium
EC	European Commission
EU	European Union
FLW	Food loss and waste
FSC	Food supply chain
GDP	Gross domestic product
GTAP	Global Trade Analysis Project
HLPE	High Level Panel of Experts on Food Security and Nutrition
IFAD	International Fund for Agricultural Development
LEI	<i>Landbouww Economisch Instituut</i> (Institute for Agricultural Economics)
MAGNET	Modular Applied GeNeral Equilibrium Tool
PFL	Processing food losses
RFW	Retail food waste
SSA	Sub-Saharan Africa
SOFA	The State of Food and Agriculture
SOFI	The State of Food Insecurity in the World
UNEP	United Nations Environment Programme
WFP	World Food Programme
WRAP	Waste & Resources Action Programme

Chapter 1

Background

Since publication of the report on global food losses and food waste (FAO, 2011), which estimated that approximately a third of the food produced for human consumption is lost or wasted globally, there have been renewed concerns about the quantity of these losses in both developing and developed countries. This is especially in light of increasing and volatile food prices and worsening global food insecurity and malnutrition for many.

Given the increasingly globalized nature of food and agricultural systems, the massive scale and magnitude of food loss and waste have brought into question their potential effect on food prices and the underlying mechanisms of price transmission. Additional concerns include the impacts on the sustainability of food systems pertaining to human nutrition and natural resources management. Most studies look at the latter dimension (FAO, 2013; FAO, 2014a; HLPE, 2014; Lipinski *et al.*, 2013; West *et al.*, 2014). However, there has been no systematic and empirical analysis of the effects of food loss and waste on food prices to inform the global policy and regulatory debate. Consequently, the objective of the present study is to bridge this information gap and provide policy-makers and practitioners with insights on potential impacts of food loss and waste reduction on prices at inter- and intraregional level. It is hoped that the findings in the paper will urge governments, policy-makers, experts, the private sector and practitioners to come together in designing better integrated and coordinated policies for tackling food loss and waste, thereby maximizing welfare impacts.

The study focuses on the linkages between the European Union (EU) and sub-Saharan Africa (SSA). The EU is a major actor in food losses and notably waste (EC, 2011), whereas SSA is the region with many of the world's poor and food insecure. Food loss and waste estimates in the EU range between 180 kg (EC, 2011) to 280 kg per capita per year (FAO, 2011). The downstream yearly food waste at consumer level in the EU is thought to be about ten times greater than in SSA. It is estimated to be around 110 kg per capita in Europe compared with only 11 kg per capita in SSA (FAO, 2011). According to estimates in *The State of Food Insecurity in the World* (SOFI), SSA had the highest prevalence of undernourishment at 23.8 percent of the total population (about one in four people) from 2012 to 2014 (FAO, IFAD and WFP, 2014).

The EU and SSA have a strong trading relationship. In fact, Europe is Africa's largest trading partner particularly with regard to agricultural commodities. It is estimated that the share in bilateral agricultural exports from Africa to Europe from 1989 to 2007 averaged 63.8 percent. During the same period (between 1990 and 2007), Africa's agricultural imports from Europe ranged between 35.2 and 37.9 percent, making Europe the largest destination and source of exports and

imports for Africa, respectively (Badiane, Makombe and Bahiigwa, 2014). Trade between the EU and SSA has been supported by a number of trade agreements. Since the 1970s, for instance, the EU has provided unilateral preferential trade access to its market for countries in SSA under the Lomé Convention, Cotonou Agreement and Everything but Arms (EBA) initiative. Further trade agreements between the EU and Africa have been negotiated under the Economic Partnership Agreements (EPAs)¹ through the Regional Economic Communities (RECs).

LEI Wageningen UR has experience in the quantification of global economic impacts of food loss and waste reductions. A previous study by LEI focused on household and retail stages of the food supply chain (FSC) in the EU, and what impacts food waste reductions at these stages would have primarily on EU economy and land use (Rutten *et al.*, 2013). A subsequent study by LEI focused on agricultural production and post-harvest handling and storage stages in the Middle East and North Africa region, and what impacts food loss reductions in these stages would have primarily on the region's economy and food security and poverty in particular (Rutten and Kavallari, 2013). Both studies build on a framework for analysing impacts using economic theory, with implications for research, policy and practice (Rutten, 2013).

The present study analyses the impacts of reductions in food losses and waste on the supply and demand of food in the global market, global food prices and their transmission to domestic food prices (consumer and producer prices) in the medium to long term. It focuses on how EU reductions in food losses and waste could influence SSA, as both a source and destination of traded agricultural and food products. Proposals in the study are in line with Rutten *et al.* (2013) in terms of potential impacts of actions taken not only by households and in retail, but also in the stages of primary production and processing of agrifood commodities in the EU. Moreover, the study provides further detail on potential impacts in terms of medium- to long-term global and local price changes in SSA and the mechanisms behind them (changes in production, consumption and trade patterns). Finally, it provides insights in terms of potential welfare impacts.

The results show that in all four scenarios, market prices decrease in both the EU and SSA with price transmission in all scenarios less than 100 percent because of the presence of import and export taxes, transport costs and trade shares. Reductions in food waste in final consumption and food losses at the primary agricultural production stages in the EU are relatively large and thus have a much stronger price impact in SSA compared with food loss and waste reductions in the other segments of the EU FSC. On aggregate, results suggest that, *ceteris paribus*, reducing food losses and waste in the EU does not benefit SSA. This outcome is the result of different, i.e. positive and negative, impacts on various actors in the SSA economy. These include: (i) producers as sellers to the EU losing out from increased competition from EU food producers; (ii) producers as buyers of intermediate agrifood inputs from the EU benefiting from lower prices and consequent lower costs; and (iii) consumers

¹ For details on the agreements, see European Commission, Overview of EPA Negotiations. Accessed October 2015. <http://ec.europa.eu/trade/policy/countries-and-regions/development/economic-partnerships>

of food commodities from the EU benefiting from lower prices. The complex interactions between supply and demand shifts, resulting from food loss and waste reduction, show that it is difficult to predict the potential socio-economic impacts of such actions, especially in a world that is continuously and rapidly changing, and that trade-offs are likely to occur. They nonetheless provide useful insights into what may happen, and provide a useful starting-point for further and more complex foresight analysis of what the world may look like in 2020 and beyond.

The report is structured in the following way. This first chapter addresses the background. Chapter 2 provides a summary of the literature on the link between food loss and waste (reductions) and food prices. Chapter 3 discusses the methodology used to analyse the potential impacts, with sections on the MAGNET model and data used; modelling food loss and waste reductions and their impacts; price linkages in the model; an analysis of the food loss and waste reduction scenarios; and the strengths and delimitations of the overall methodology. The final chapters (4, 5 and 6) contain, respectively, the results, discussion, conclusions and potential policy implications.

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Chapter 2

Food loss and waste (reductions) and food prices: a summary of the literature

FAO (2011) estimated that nearly 1.3 billion tonnes of food are lost and wasted per year, yet approximately 805 million people worldwide were thought to be chronically undernourished between 2012 and 2014. In particular, slow progress has been registered in improving access to food because of limited income growth, high poverty rates and poor infrastructure, which have made physical and distributional access a major challenge (FAO, IFAD and WFP, 2014).

Significant food losses and waste on the one hand, and (extreme) hunger and vulnerability on the other, suggest that reducing food losses and waste could relieve part of the pressures on scarce natural resources and contribute towards enhanced food and nutrition security.

- *Food loss* is defined as the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption and takes place at the production, post-harvest and processing stages in the FSC.
- *Food waste* is defined as food loss occurring at the end of the FSC in the retail and final consumption stages (Parfitt, Barthel and Macnaughton, 2010).
- *Food security* is defined as “... when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO, 1996).

The impacts of tackling food loss and waste on the food system and the wider economy are mediated by changes in prices in agrifood markets. The price mechanism in a well-functioning competitive market ensures that demand equals supply and scarce resources are allocated in an optimal way. Prices respond to changes in relative scarcities, i.e. prices tend to fall in the presence of excess supply and rise in the presence of excess demand.² A broader definition of scarcities in agrifood markets and their link to food price hikes and volatility are discussed in detail in the report by the High Level Panel of Experts on Food Security and Nutrition (HLPE, 2011).

² Agrifood markets in reality do not always function perfectly because of the existence of, for example, economies of scale and market power in the agrifood industry, and the increasing importance of product quality and differentiation, which gives food producers/suppliers the ability to influence or set prices according to their own interests. These may not be in line with perfect market dynamics (Sexton, 2013).

Since the generation of food loss and waste essentially reduces net food supply available for human consumption, the expectation is that tackling food losses and waste will contribute towards increasing net food supply and could lower food prices, locally and globally (FAO, 2011; Lipinski *et al.*, 2013; Lundqvist, de Fraiture and Molden, 2008). The various actors along the food value chain may experience the impact of lower prices differently. According to the literature, food producers are expected to profit from reducing food losses since this allows them to sell more and produce at a lower cost (per unit of food sold) so that their incomes increase. Similarly, consumers are expected to benefit from reducing food waste since it saves them money that they can spend on other items (both food and non-food products) and it may lower the price of the remaining food available in the market. Note that lower prices are beneficial to net food consumers but may be harmful to net food producers.

A complicating factor is that relatively low food prices are also seen as an important factor explaining the existence of food loss and waste. Specifically, in developed countries, the increasing availability and variety of food, decreasing prices and lower share of income spent on food are said to have led to a greater tolerance of food waste. Under these circumstances, it may simply be convenient from a consumer perspective to waste food (BCFN, 2012). Similarly, in developing countries, it may be rational for agrifood producers, who apply a limited short-term cost-benefit analysis, to incur food losses if costs involved to tackle food losses outweigh the benefits in terms of increased sales at lower prices (FAO, 2011; Lipinski *et al.*, 2013). Either way, food losses and waste are likely to be symptomatic of a second-best (i.e. imperfect) world in which the benefits of inaction regarding food losses and waste outweigh the costs for the actor(s) involved. However, from a welfare-economics perspective, taking into account broader societal impacts, it may be worthwhile to address the underlying causes of food loss and waste, at least to a certain extent. For instance, systems thinking supports an integrated agricultural and food system approach where food utilization is optimized and loss and waste of resources are reduced (Halloran *et al.*, 2014).

Rutten (2013) uses basic economic theory of food supply and demand to study the impacts of tackling food loss and waste in the short and long term. These impacts differ from the original magnitude of food loss and waste since prices will change (i.e. fall). The impacts are shown to depend on the extent to which the food losses and waste are avoidable, factors that cause them to arise (notably food prices), and the costs associated with measures to reduce them. Interactions within the FSC and the broader economy also play a role and intertemporal effects are shown to matter. On the demand side, tackling food waste will incur trade-offs because the reallocation of spending on previously wasted food causes some producers to be worse off and some to be better off. For example, if consumers were to waste fewer vegetables, they would need to buy fewer vegetables (assuming that their preferences have not changed). This would make vegetable producers worse off since their sales go down. However, consumers may spend the money they saved, for example, on meat or perhaps on non-food products, which would benefit meat or non-food producers. If consumers delay spending the money they saved from reducing vegetable waste, these impacts may occur only in the long term. On the supply side, producers tackling losses may have to incur welfare losses in the short term, due to

costs involved and/or a fall in revenues because of declining agrifood prices, with gains in terms of increased sales, if any, occurring later. Consequently, the impacts, notably on food security and welfare, are ambiguous and need to be investigated in more detail in applied and context-specific studies.

The economic impacts of tackling food loss and waste via changes in prices and how they ripple through the global economy have received little attention in the few recent studies on food loss and waste. This is also because of a general lack of consistent and reliable data, fed by differences in and/or disagreement on definitions and methods of data collection across countries. A study focusing on healthy and sustainable diets, known as the “protein puzzle”, which also looked into the issue of food waste, found that a reduction of food waste modelled via a 15 percent global supply chain efficiency increase reduces agricultural prices by about 4 percent, which generates an increase in food consumption (Westhoek *et al.*, 2011). Further studies focusing on food waste or loss reductions, using up-to-date data, focus on specific regions of interest, specifically the EU (Rutten *et al.*, 2013) and the Middle East and North Africa (Rutten and Kavallari, 2013). These studies did not specifically consider price transmission. Nevertheless, past empirical work following the food price hikes of 2007/2008 suggests considerable heterogeneity in transmission of international prices to domestic prices across regions, countries, commodities and time, warranting further research (HLPE, 2011; Minot, 2011).

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Chapter 3

Methodology

This study employs a scenario analysis to investigate the impacts of reductions in food loss and waste in the EU on SSA, with a focus on price effects. Scenario analysis is an important tool to help policy-makers, researchers and other stakeholders to envision what the future may look like, and guides the formulation of policies that are contingent on future expectations. Following Rutten *et al.* (2013), we implement a set of food loss and waste reduction scenarios that demonstrate what would happen if food loss and waste in the EU were reduced by 50 percent in 2020 (the target set by the EU for the milestone of food waste; EC, 2011).³ These “what if” scenarios are run with the MAGNET model and compared with a reference baseline scenario reflecting “business as usual” (BaU). The results (see Chapter 4) thus illustrate the impacts of a 50 percent reduction in EU food loss and waste on various socio-economic indicators in 2020, all else being equal (the so-called *ceteris paribus* condition).

The following sections discuss the methodology in more detail. First, we describe the MAGNET model and data used. This is followed by a brief treatment of the novel way in which food loss and waste reductions, and their impacts are modelled in relation to other (potential) approaches. We also outline the price linkages in the model – the focus of the study. Next, we discuss the scenarios that have been implemented. The final section delves into the strengths and delimitations of the approach.

3.1 MAGNET MODEL AND DATA

MAGNET (Modular Applied GeNeral Equilibrium Tool, release version 2) is a multisector, multiregional computable general equilibrium (CGE) model that has been widely used to simulate the impacts of agricultural, trade, land and biofuel policies on global economic development (Woltjer *et al.*, 2014). MAGNET is based on the Global Trade Analysis Project (GTAP) model but can be extended in various directions in a modular fashion, depending on the policy questions at hand.

The GTAP core model accounts for the behaviour of households, firms and the government in the global economy, and how they interact in markets (Hertel, 1997).

³ The EC announced new targets for the circular economy in 2014, which specified an objective to reduce food waste by at least 30 percent between 1 January 2017 and 31 December 2025 (EC, 2014). On 16 December 2014, the EC announced the withdrawal of the Circular Economy package (proposed in July 2014) from the EC’s new work programme. The package addressed policy and regulatory areas such as waste (including food waste), recycling, incineration and landfill. A new proposal is targeted for the end of 2015. We do not expect the incorporation of the new target to change our results significantly. The direction of effects remains the same. However, the magnitude will be lower because of lower target reductions but higher because of starting from a larger base economy.

For the purpose of this study, MAGNET, compared with standard GTAP, employs:

- a more sophisticated production structure, accounting for the inherent difference in the ease of substitution between land and non-land factors of production;
- a more sophisticated consumption structure, which acknowledges that, while household demand for food rises over time as incomes grow, the share of the household budget allocated to food declines and, within food consumption, households substitute staple foods with fruit and vegetables, animal products and other processed foods;
- segmented labour and capital markets, allowing for differences in factor remunerations between agricultural and non-agricultural sectors as observed in reality; and
- an improved modelling of the land market, allowing land supply to respond to changes in land price, with the latter rising more if land is relatively more scarce.

All extensions have been documented in detail in Woltjer *et al.* (2014). A non-technical summary of the complete model used in this study is given in Appendix 1.

The GTAP database⁴ version 8.1 (data used in our model) reflects the state of the world economy in the year 2007. The 129 countries/regions and 57 sectors/commodities of the database have been aggregated into more manageable categories, namely eight regions, 19 sectors and the standard five factors of production (Table 1). This aims to focus on the sectors and regions of interest for the research question (known as “flexible aggregation”), while keeping a reasonable simulation run time for the model scenarios.

The regional structure divides the world along broad geographic lines, with the EU and SSA – our main regions of interest – identified separately. The sectoral division distinguishes the main agrifood commodities and segments of the FSC for which food loss and waste data are available. This includes both primary agricultural commodities and the associated processed categories that process commodities further into final consumer goods. Specifically, the first eight categories in Table 1 cover agricultural, i.e. land-using, sectors consisting of food-related crops (cereals, vegetables and fruit, oilseeds, and sugar cane and beet), livestock and livestock produce (cattle, chicken, raw milk) and other non-food related agricultural produce. Fisheries are another primary sector included. The following sectors are processed food categories, including red meat products, white meat products, vegetable oils, dairy products, processed rice, sugar (raw sugar, molasses and other sweeteners), and other food and beverages⁵ (referred to from now as “other food”), all of which have strong linkages with the primary agricultural sectors. A manufacturing sector comprises all industries, excluding the processed food sector. With regard to services, a retail sector is distinguished, which covers retail and wholesale trade, as well as hotels and restaurants, through which a great deal of food is indirectly con-

⁴ The database is fully documented (Narayanan, Aguiar and McDougall, 2012) and contains comprehensive and consistent data on production, consumption and trade among countries in the world.

⁵ This category also includes tobacco products.

sumed (this sector is referred to as “retail” from now on). The remaining services have been grouped together. The model retains the standard GTAP specification of five factors of production, including skilled and unskilled labour, capital, land and natural resources.⁶

TABLE 1
MAGNET regions, sectors and factors of production

Regions*		Sectors*	
EU27	EU27	CER	Cereals: paddy rice, wheat and other grains
ROE	Rest of Europe	v_f	Vegetables, fruit and nuts
NAM	North America	osd	Oilseeds
CSA	Central and South America	c_b	Sugar cane, sugar beet
ASIA	Asia	ctl	Cattle, sheep, goats, horses
OCE	Oceania	chk	Chicken: other animal products, including poultry, eggs, swine ...
MENA	Middle East and North Africa	rmk	Raw milk
SSA	Sub-Saharan Africa	OAG	Other agriculture: other non-food related crops and animal produce
		fsh	Fishing
		rmt	Red meat: cattle meat products
		wmt	White meat: other meat products
Factors of production		vol	Vegetable oils and fats
Land	Land	mil	Dairy products
UnSkLab	Unskilled labour	pcr	Processed rice
SkLab	Skilled labour	sgr	Sugar: raw sugar, molasses and other sweeteners
Capital	Capital	FBT	Other food, beverage and tobacco products
NatRes	Natural resources	MNF	Manufacturing, excluding processed foods
		ret	Retail: retail, wholesale, hotels and restaurants
		SVC	Other services

* Abbreviations with capital letters are aggregations of GTAP countries or sectors, otherwise they are present as such in the GTAP database.

⁶ The latter category comprises all resources used in the production of goods, excluding labour, capital and land. It therefore includes water and minerals, for example.

3.2 MODELLING FOOD LOSS AND WASTE (REDUCTIONS) AND IMPACTS

The modelling of food loss and waste and/or reductions therein is very much in its infancy, primarily resulting from a lack of reliable and consistent data. This study uses FAO (2011) data on food loss and waste in Europe (including the Russian Federation) as a proxy for food loss and waste data in the EU (Table 2),⁷ the most reliable regional data source available, which distinguishes food loss and waste percentages by commodity group and stage in the FSC.

Food loss and waste streams are lacking in MAGNET (as in GTAP or in any other global economic model) and would require a rebalancing of agrifood flows and value streams throughout the global economy. The detailed data needed to do this currently do not exist. However, given that food loss and waste merely represent an efficiency loss, there is a solution to work around the problem.

On the *supply* side (see first two columns of Table 2), food loss reductions can be modelled via productivity shocks. Tackling food losses, given inputs into production, increases outputs of agricultural sectors or, given outputs, reduces the use of inputs into the production of these sectors, implying a rise in productivity by 50 percent of the shown percentages (as assumed). In the first stage of agricultural supply, we assume uniform productivity increases for all inputs (i.e. the shocks are implemented as total factor productivity shocks). This is because we do not know whether food losses occur in the use of a certain factor (e.g. labour) or the

TABLE 2

Food loss and waste estimates by commodity and stage in the food supply chain (FSC) for Europe (including the Russian Federation)

Commodity	Agricultural supply (production, post-harvest handling and storage)*	Processing and packaging	Distribution (retail)	Consumption
<i>Percentage of production</i>				
Cereals	6	5.25**	2	25
Roots and tubers	29	15	7	17
Oilseeds and pulses	11	5	1	4
Fruit and vegetables	25	2	10	19
Meat	3.8	5	4	11
Fish and seafood	9.9	6	9	11
Milk	3.8	1.2	0.5	7

* Percentages for agricultural production and post-harvest handling and storage have been added together.

** A simple average of the two percentages (0.5 percent and 10 percent) in the original table.

Source: adapted from FAO, 2011 (Annex 4).

⁷ Data used for modelling in this paper are those provided by the FAO 2011 study, since reliable EU data are lacking. A study on EU27 by BIO IS (2010) cautions against using EU data since many figures mentioned are extrapolations. Moreover, the BIO IS study does not provide data on food waste at primary production in the agricultural and fisheries sectors, nor for other regions.

use of a certain intermediate input (e.g. seeds) and nor do we know the nature of the measure taken or technology employed to tackle food losses (data are lacking). This approach to modelling agricultural food losses was first developed and used by Rutten and Kavallari (2013). In the second stage of food processing, we assume uniform productivity increases of intermediate inputs (e.g. cattle) used to make a specific processed food (e.g. red meat). For both stages, the model subsequently determines the optimal input-output mix, whereby losses on both the input and output side will be reduced.

On the *demand* side (see last two columns of Table 2), food waste reductions can be modelled by productivity shocks as before, the retail sector's demand for intermediate commodities (e.g. vegetables and fruit used by restaurants) and taste shocks in final consumption by households. The latter are incorporated in the model via taste shifters – households that reduce their food waste by 50 percent as assumed need to consume less food to maintain the same level of well-being as before, which results in lower consumption of the respective food commodity. In the absence of knowledge on how the saved expenditures will be used, it is assumed that demand for all (food and non-food) commodities increases by the same proportion and to the extent that households remain within their budget constraint.⁸ This approach to modelling food waste is that of Rutten *et al.* (2013).⁹

Promising avenues for improving the current methodology are first to incorporate food loss and waste percentages explicitly throughout the FSC, from farm to fork, and taking into account international trade and, in a second stage, to make the loss and waste endogenous in the model, depending on (relative) input and output prices. A similar approach is proposed by Irfanoglu *et al.* (2014) in a summary paper using a partial equilibrium framework but, at the time of writing this paper, the methodology and results are not yet publicly available.

A large body of literature has focused on expressing food loss and waste in terms of the value of the resources (land, water), the output that might have been realized (production, consumption, nutrition) and the negative external effects that might have been avoided (emissions), taking into account the life cycle of agrifood products (see BCFN [2012] for an overview). However, such valorizations merely say something about the scale of the problem, not the actual impacts, since they

⁸ If, as an extreme alternative, it is assumed that households would spend all savings from previously wasted foods on food commodities, then the net impact on agrifood sectors would be much less (in total nil), as would be the impact on land use and the economy at large. The main impact would be on EU consumers in terms of increased welfare. The other extreme is that households spend all savings on non-food commodities (products and services), in which case agrifood sectors would be hurt more. The assumption made lies in between these two extremes and does some justice to consumer preferences which, as incomes rise over time, shift from food towards non-food commodities, and within food away from staple foods towards more luxurious and nutritionally diverse food items, respectively known as “Engel’s law” and “Bennett’s law” (Bennett, 1941).

⁹ Once the preference shift is implemented, it will trigger a general equilibrium response to the changing demand pattern, which is likely to change household income and expenditures. Since the saved expenditures from food waste benefit household consumption of all food commodities, including the commodities for which taste originally declines, decrease in demand for this particular commodity is somewhat dampened. For all other commodities, household demand will increase, given household income.

ignore interactions between demand and supply, the role of the price mechanism therein and, more generally, interactions between actors and sectors in the agricultural sector, the food system and the wider (national and global) economy. Given the scale of the problem, these second-order effects could be quite considerable. For example, reducing food losses on the supply side (food waste on the demand side) could lower food prices quite considerably, leading to a change in demand (supply) of food so that the resulting impact is likely to differ from the value of resources or output embodied in the food loss (or waste) itself. Economic theory demonstrates that this is indeed the case (Rutten, 2013). The present study takes these interactions, and notably price effects, into account.

Finally, a recent study uses a partial and econometrically estimated model of the relationship between food waste and spending on food, with a focus on the United Kingdom (WRAP, 2014). Its main findings are that 40 percent of the observed reduction in food waste in the United Kingdom from 2007 to 2010 is attributable to an updated food waste reduction activity index¹⁰ and around 35 percent to higher real food prices. Fifty percent of household budget savings of 1.9 billion pounds per year resulting from reductions in food waste (called the food waste reduction “dividend”), was spent on more luxurious food items; the other half was saved or spent on other items. By the partial nature of the model and its focus on the United Kingdom, this study cannot incorporate global general equilibrium effects, including price impacts, and so it is largely complementary to this and previous CGE studies. Note that evidence of trading-up was found by Rutten *et al.* (2013), and is incorporated in this study by nature of the modelling of consumer preferences and food loss and waste (see also MAGNET model description).

3.3 PRICE LINKAGES IN THE MODEL

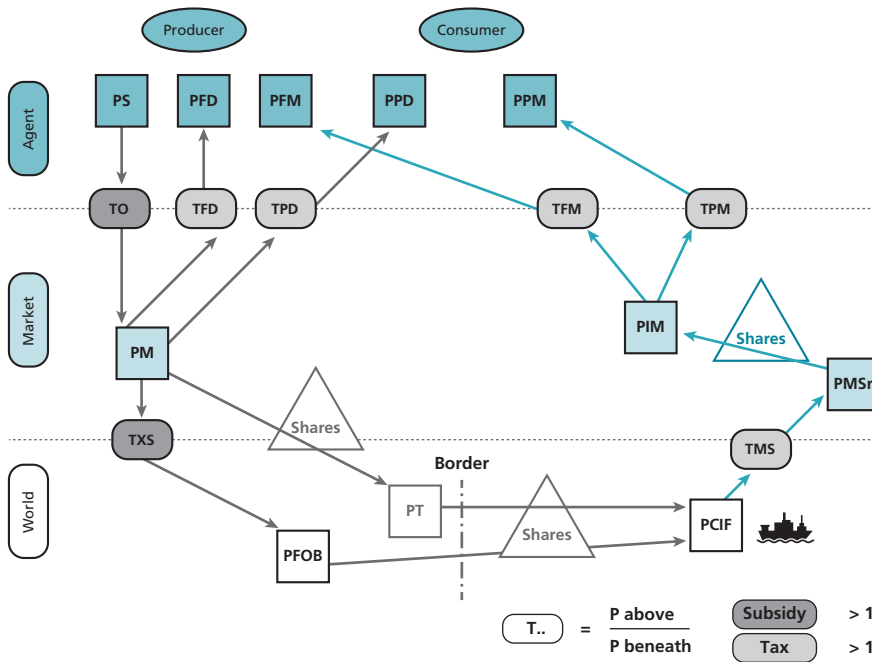
Price transmission analysis measures the effect of prices in one market on prices in another. The topic has received a great deal of attention since the degree of price transmission is broadly indicative of the extent to which markets are functioning well and without friction (FAO, 2004). International price transmission analysis studies the relationship between world and local prices for a given commodity, and is the focus of this study.

The field of international price transmission is traditionally dominated by econometric analysis and extremely disconnected from simulation-based model analysis, such as the CGE modelling used in this study, despite its strengths of being able to demonstrate economy-wide implications of price changes (Siddig and Grethe, 2014). This is not surprising since econometric price transmission models are built on high frequency (daily, weekly or monthly) data and short-term adjustment processes, whereas CGE models are concerned with structural data (annual averages) and medium- to long-term impacts (including endogenous price effects). In future, more detailed data on prices may become available in relation to food loss and waste, which would facilitate an integrated approach such as that proposed and implemented by Siddig and Grethe (2014). In this study, however, we simply trace

¹⁰ The food waste reduction activity index (FWRAI) is an index developed by WRAP and comprises five components. For details, see WRAP (2014).

FIGURE 1

An overview of world and domestic producer and consumer price linkages in the Global Trade Analysis Project (GTAP)



Notes: (i) For ease of exposition, the government as an agent is not included. The price linkages for the government are analogous with those of consumers. Simply replace the "P" for private households by a "G" for government. (ii) Taxes are *ad valorem* and are introduced as powers (1 + ...). Taxes are defined by the "price above" divided by the "price beneath" (e.g. agent over market prices, or market over world prices). Depending on the tax in question, a power of the tax greater than one indicates either a subsidy (a negative tax; shaded dark grey in Figure 1) or a tax (shaded light grey).

Source: authors' elaboration.

price impacts through the GTAP-based MAGNET model, following food loss and waste reduction shocks imposed in the scenarios.

It is helpful to understand price linkages in the MAGNET model. Both GTAP and MAGNET distinguish *agent prices*, or prices received by the agents in the model (firms or producers, private households or consumers, and the government); *domestic market prices*; and *world market prices*, which are all linked via various taxes. Figure 1 shows a simplified schematic overview of the interrelationships between world and domestic commodity prices in the MAGNET model, focusing on producers and consumers.

Beginning at the top left of Figure 1, firms produce and supply commodities to the market at the supply price (PS). The supply price of a commodity becomes the market price of a commodity (PM) after adding an output tax (TO). Commodities can subsequently be sold domestically or exported. Domestic sales can be subdivided into sales to other producers as intermediate inputs. These inputs are taxed by

TFD, the domestic tax on firms, resulting in PFD, the price paid by firms for domestic intermediate inputs. The domestic output can also be sold to consumers. Sales to consumers are taxed by TPD, the domestic tax on private households, resulting in PPD, the price paid by private households for domestic commodities. If commodities are exported instead, they are taxed by an export tax (TXS), generating the “free on board” price (PFOB) for a commodity from the source region in question. The latter price, combined with the international transport margin price (PT) – which is a composite of the market prices of commodities “sold” by source regions to an international transport sector – feeds into the “cost, insurance and freight” price (PCIF) of an imported commodity. After bilateral import taxation (TMS), the import price by source region “r” results (PMSr), which for all source regions is combined in a composite import price for a commodity paid by the destination region (PIM). Note that now the perspective has changed from the source/exporting region to the destination/importing region, hence the change of colour of the arrows from grey to blue. As with domestic sales, composite imports of a region are distributed over the different agents again, whereby imports of foreign intermediate inputs by firms are taxed (by TFM), resulting in the price paid by firms for imported intermediates (PFM). Imports by private households are taxed (by TPM), resulting in the price paid by private households for imported commodities (PPM). This closes the loop from producers or firms in one location (for example, the EU or SSA) to consumers or private households in another (for example, SSA or the EU).

Food loss and waste reductions to be modelled enter these relationships by affecting the price of a certain commodity at a specific stage of the FSC (Table 2), which subsequently has knock-on effects on other prices (Figure 1). On the *supply* side, lower food losses in the EU imply that fewer agricultural inputs will be needed per unit of agrifood output, leading to lower unit costs and prices and increased outputs. This increases EU supply and exports of agrifood commodities to the world market, and SSA in particular, and may increase or decrease the EU’s demand for intermediate inputs from the world market, and SSA in particular. The impact would depend on whether the output expansion effect or the input and cost saving effect dominates. Overall, this is expected to lower agrifood prices in the world, and in SSA in particular, benefiting net food consumers but harming net food producers.

On the *demand* side, lower food waste in the EU implies a lower demand for agrifood commodities (and increased demand for other products and services), which results in lower agrifood prices and an increased orientation away from domestic agrifood sales towards exports to the world market, and SSA. As before, agrifood prices in SSA are expected to fall. How much the SSA economy is affected by the aforementioned changes in the world market depends on trade (export and import) shares in production and consumption. The impacts of reducing food loss and waste in the EU on SSA will be investigated in more detail in Chapter 4. In reality, trade between the EU and SSA is influenced by many more factors that have been kept constant in the quantitative analysis, so these outcomes may or may not result in practice.

While this is not the focus of the study, it is important to realize that there are also vertical price relations in the model that play a role. Specifically, the supply price of a commodity is a composite of value added (factor input) and intermediate input prices. Hence, primary agricultural commodity (e.g. cattle) prices contribute

to processed food (e.g. red meat) prices and subsequently to food-related service (e.g. restaurant) prices. The international price transmission will therefore be influenced by the relative importance of primary versus processed food versus food services in final food production and consumption. The main factors generally affecting price transmission from world to domestic markets (and vice versa) have been summarized in Appendix 2.

3.4 SCENARIOS

We adopt a series of food loss and waste reduction scenarios, where food loss and waste percentages in the EU are reduced by 50 percent in 2020, taking the FAO data on food loss and waste for the Europe region as the point of departure (Table 2) and using the method specified in Section 3.2. Note that these food loss and waste reductions could be the result of an investment in technology on the part of food producers or a behavioural change by consumers, perhaps induced by tax and subsidy instruments or regulatory measures that stimulate food loss and waste reductions, respectively penalizing food loss and waste behaviour.¹¹ As shown in Tables 1 and 2, FAO commodity groupings and MAGNET sectors are not in perfect correspondence and, where necessary, are mapped using assumptions in line with Rutten and Kavallari (2013) and Rutten *et al.* (2013).¹² We assume that these food loss and waste reductions will be realized over the period 2012–2020, which is the period of interest for EU member states. The shocks have been combined in a total of four food loss and waste reduction scenarios, grouped by stage of the FSC (Table 3).

The first scenario, *reducing agricultural food losses* (AFL) in supply, applies output-augmenting technological change shocks that target a 50 percent reduction in food losses to commodities produced in the first stage of the FSC, primary agriculture (2nd column in Table 3). This implies that all intermediate and factor inputs used in the production of primary agricultural commodities become more productive by the shown percentages (e.g. 3 percent for cereals).

The second scenario, *reducing food losses in food processing* (PFL), applies intermediate input-augmenting technological change shocks that target a 50 percent reduction in food losses to commodities produced, using primary agricultural commodities, in the second stage of the FSC, food processing (3rd column in Table 3). This implies that the intermediate inputs (primary agricultural commodities) used in the production of processed foods become more productive by the shown percentages (e.g. raw milk is used 0.6 percent more efficiently in producing dairy products, including processed milk).

¹¹ In future, once food loss and waste streams can be modelled explicitly as an outcome of underlying economic processes, specific (policy) measures that induce food loss and waste reductions could be analysed (see also Section 3.2).

¹² These are that (i) the category “sugar cane, sugar beet” inherits food loss and waste shocks from the FAO category “roots and tubers”; (ii) primary agricultural commodities without the adequate processed food equivalent in MAGNET have been mapped to their most important destination sector, “other food” (relevant for “fishing”, “vegetables, fruit and nuts”, with “cereals” mapped into “processed rice” and “other food”); (iii) retail and households are assumed to buy processed foods, with the exception of “fishing” and the “vegetables, fruit and nuts” commodities.

TABLE 3
European Union (EU) food loss and waste reduction scenarios

SCENARIO →	Reducing AFL supply		Reducing PFL		Reducing RFW		Reducing final CFW	
Stage in FSC →	<i>Agriculture</i>		<i>Food processing</i>		<i>Retail</i>		<i>Consumption</i>	
Shocks (percentage change) applied by commodity and stage in FSC	Output- augmenting technological change applied to:		Intermediate input-augmenting technological change applied to:		Intermediate input-augmenting technological change applied to:		Negative taste change applied to:	
Cereals	input use in cereals	3	cereal use in processed rice and "other food"	2.63	processed rice and "other food" use in retail	1	household demand for processed rice and "other food"	12.5
Sugar cane, sugar beet	input use in sugar cane, beet	14.5	sugar cane, beet use in sugar	7.5	sugar use in retail	3.5	household demand for sugar	8.5
Oilseeds	input use in oilseeds	5.5	oilseeds use in vegetable oils and fats	2.5	vegetable oils and fats use in retail	0.5	household demand for vegetable oils and fats	2
Vegetables, fruit and nuts	input use in vegetables, fruit and nuts	12.5	vegetables, fruit and nuts use in "other food"	1	vegetables, fruit and nuts use in retail	5	household demand for vegetables, fruit and nuts	9.5
Cattle, other animal products	input use in cattle, other animal products	1.9	cattle use in red meat and other animal product use in white meat	2.5	red and white meat use in retail	2	household demand for red and white meat	5.5
Fish	input use in fishing	4.95	fish use in "other food"	3	fish use in retail	4.5	household demand for fish	5.5
Raw milk	input use in raw milk	1.9	raw milk use in dairy	0.6	dairy use in retail	0.25	household demand for dairy	3.5

The third scenario, *reducing retail food waste (RFW)*, applies intermediate input-augmenting technological change shocks that target a 50 percent reduction in food waste in the third stage of the FSC, retail (4th column in Table 3). This implies that retail use and demand for food commodities or products per unit of retail sector output fall by the shown percentages (e.g. 5 percent fewer vegetables, fruit and nuts are used in producing one unit of food retail services).

The fourth scenario, *reducing final consumption food waste (CFW)*, applies negative taste shocks that target a 50 percent reduction in food waste in the fourth stage

of the FSC, final consumption (5th column in Table 3). This implies that household demand for food commodities or products falls by the shown percentages (e.g. 8.5 percent for sugar).¹³

Finally, all scenarios have been combined into a fifth overall *food loss and waste (FLW) reduction* scenario. This allows for an analysis of effects by food loss/waste reduction effort in the EU by segment of the FSC.

The scenarios will be implemented in addition to a baseline BaU scenario. This scenario reflects a future in which major socio-economic drivers follow current trends, and assumes that there are no major policy changes. It projects the economy forward, from 2007 onwards, using USDA (2012) data on gross domestic product (GDP) and population. It assumes a return towards long-term steady growth after the global recession and financial crisis, and decreasing population growth across the world with the exception of SSA. Labour supply follows the growth path of population, whereas capital follows that of GDP, ensuring that the capital-output ratio is roughly constant over time, as we generally observe land productivity (i.e. yield) projections are derived from IMAGE (Integrated Model to Assess the Global Environment) and based on FAO projections up to 2030 (FAO, 2003; FAO, 2012). Technological progress is assumed to be mainly labour saving and is faster in manufacturing (followed by agriculture) relative to services. This is consistent with more pessimistic views about the future of agricultural productivity as represented by predictions of stable or even rising real agricultural prices in the future. We assume that in BaU (from 2007 to 2012, and onwards) wasteful behaviour in the EU (or elsewhere) regarding food does not change. Figure 2 shows the main drivers of change in BaU.

3.5 STRENGTHS AND DELIMITATIONS

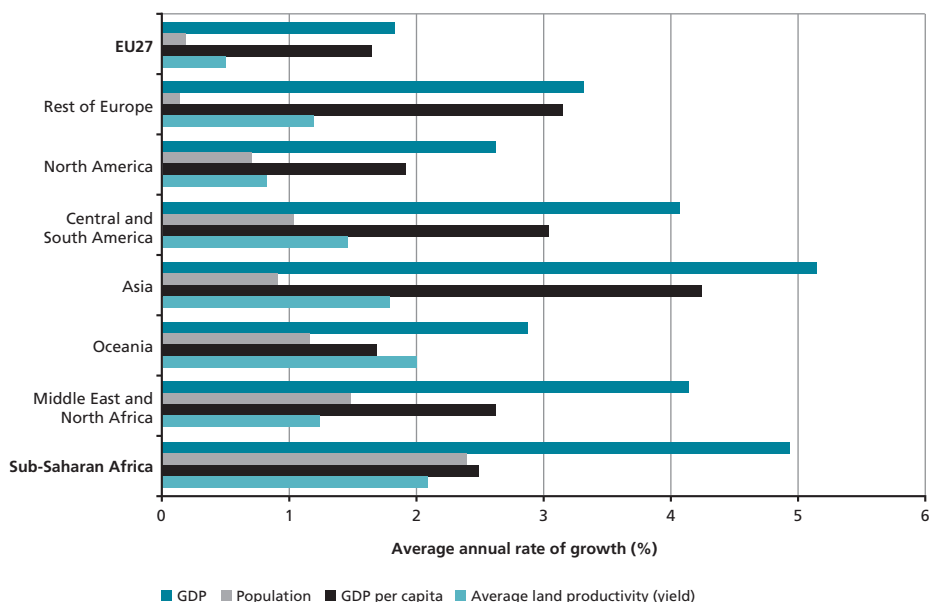
Although CGE type models such as MAGNET are commonly used in scenario analyses, there are drawbacks. While such models can take into account global general equilibrium effects and associated interactions between actors, sectors and markets, these occur on an aggregate scale. The level of detail is essentially being restricted to the selection of regions, sectors and factors of production (as included in Table 1). MAGNET nonetheless has specifically been designed for policy analyses in the domains of agriculture and trade (see Section 3.1 and Appendix 1) and performs relatively well compared with other global partial or general equilibrium models as demonstrated in the AgMIP Global Economic Model Intercomparison project (von Lampe *et al.*, 2014). In discussing the results, we will elaborate on the further data and modelling work needed for more detail.

As indicated in the summary of the literature (Chapter 2), low food prices may cause food loss and waste, which may not be completely avoidable, and there may be costs involved in tackling these losses. In the absence of consistent and reliable

¹³ The shocks for households are incorporated in MAGNET via a negative taste shifter, which results in lower consumption by households of the respective food commodity items. In the absence of knowledge on how the saved expenditures will be used, it is assumed that demand for all (food and non-food) commodities increases by the same measure and to the extent that households remain within their budget constraints.

FIGURE 2

MAGNET baseline (Business as usual – BaU) gross domestic product (GDP), population and yield assumptions, 2012–2020



Source: authors' elaboration. GDP and population (USDA, 2012); yield (FAO, 2003).

endogeneity); that 50 percent is avoidable (according to the target set by the EC); and, by nature of the model, the focus is on the medium- to long-term impacts (in 2020) that arise when food loss and waste are reduced (as described in Section 3.2). The resulting welfare impacts represent boundary values for how much reducing food loss and waste by 50 percent may cost for it to be worthwhile from a welfare-economic perspective. In discussing the results, we will elaborate on the implications of these assumptions.

Regarding market functioning and price transmission (Section 3.3 and Appendix 2), the model abstracts from market imperfections (apart from rigidities in labour, capital and land markets) and market failures (most important, economies of scale and imperfect competition), and focuses on medium- to long-term price transmission effects within the given MAGNET model setup. Thus, the focus is on explaining price transmission effects arising from economic characteristics, including trade shares and the relative importance of commodities in the domestic economy.

Chapter 4

Results

We empirically trace and report the price links elaborated in Section 3.3 of this paper. This is done for each stage of the FSC individually, before presenting the results for a case where all elements in the chain from farm to fork reduce their food loss and waste by 50 percent. Finally, to facilitate reporting of the results, all food commodities are grouped into four categories.

1. *Primary food* category, which constitutes all primary agricultural commodities (cereals, vegetables and fruit, oilseeds and pulses, cane and beet crops, livestock including cattle and chicken, raw milk and fish).
2. *Processed food* category, which consists of processed rice, sugar, red meat, white meat, vegetable oils and fats, dairy products and other food and beverage products.
3. *Consumed food* category, which includes all processed foods and fish, fruit and vegetables (otherwise part of primary food commodities), since they are consumed by households directly.
4. Finally, a broader aggregate is defined: the *food* category, which includes the commodities mentioned in both categories 1 and 2 above.

4.1 REDUCING FOOD LOSSES IN AGRICULTURAL SUPPLY

SUMMARY

If the EU reduces food losses in agricultural supply, producers demand fewer inputs to produce more output. Increased supply in the EU helps bring the market price of food in the EU down, and some of this reduction is transmitted to international markets, including SSA. Consumers in SSA clearly benefit from cheaper imports of food commodities from the EU. Producers face a mixed bag: they benefit from cheaper imported intermediate inputs from the EU, but lose out from cheaper food imports that compete with domestically produced food in SSA, forcing them to cut prices on their domestic sales. Moreover, SSA's exports to the EU have to compete with lower priced domestic food in the EU. In response to increased competition in both domestic and foreign markets, producers in SSA produce less than before.

At an aggregate level, the results show that reducing food losses in agricultural supply in the EU by 50 percent in 2020 is equivalent to increasing the production of primary food by about 4 percent in comparison with the BaU outcome in 2020.

With domestic demand in the EU for primary food commodities increasing only by 2 percent, this translates into a decrease in the market price of primary food by around 6 percent in 2020 compared with BaU (Table 4). Note that these numbers are for the category as a whole and individual commodities within the group vary in their amount of price decrease.

As losses in primary food commodities are reduced, both the price and production impacts are highest for these commodities. The other categories (processed food, consumed food and food) also see some changes because they include (some) primary food commodities either by definition or as intermediate inputs.

The price reduction in the EU is transmitted to producers and consumers in SSA. How much is transmitted depends on taxes and trade shares. The mechanism is outlined below, starting with the price of primary food in the EU, along the lines of the price linkage figure (Figure 1) introduced in Section 3.3. The results for key price variables are provided in Table 5. The table shows that consumers benefit from lower prices while producers, to some extent, benefit from reduced prices of imported intermediate inputs but lose out on prices they obtain for their sales.

With a fall in the market price of primary food in the EU (given export taxes), the export price of primary food that the EU exports to SSA will fall. The price that SSA pays when this food reaches a port in SSA will include some transport costs as well. Finally, the market price of the primary food arriving in SSA from the EU (*price of products imported from the EU*) will also include any import taxes that SSA imposes on the imports. All these elements explain why price transmission is less than 100 percent. In our analysis, none of these additional elements – export and import taxes and transport costs – changes across scenarios.

The goods go through further stages before actually reaching the consumer or the producer in SSA. Note that in MAGNET, consumers and producers obtain imported goods as a composite of all imports. The *composite price of imported products* is determined as the share-weighted sum of imported goods from all the different sources, where the weights are shares of SSA imports coming from different regions. Hence, only a fraction (share of EU exports to SSA in SSA's total imports of primary food) of the reduction in the primary food price in the EU will be transmitted to the market price of primary food in SSA. This share is about

TABLE 4
Impact on the European Union (EU) market in 2020, agricultural food losses (AFL) scenario

Category	Production volume	Domestic demand	Market price
<i>Percentage difference from BaU</i>			
Primary food	3.66	2.075	-5.79
Processed food	0.517	0.365	-0.63
Consumed food	0.998	0.587	-1.33
Food	1.112	0.686	-1.61

Source: MAGNET model results.

TABLE 5

Price transmission to sub-Saharan Africa (SSA) in 2020, agricultural food losses (AFL) scenario

Category	Price of products imported from the EU	Composite price of imported products	Consumer price for imports	Consumer price	Imported input price	Input price	Producer price
<i>Percentage difference from BaU</i>							
Primary food	-4.79	-0.932	-1.03	-0.39	(-0.5, -1.8)	(-0.4, -0.5)	-0.3552
Processed food	-0.48	-0.196	-0.18	-0.15	–	–	-0.1241
Consumed food	-0.79	-0.611	-0.22	-0.25	–	–	-0.206
Food	-1.01	-0.592	-0.26	-0.29	–	–	-0.2475

Source: MAGNET model results.

15 percent.¹⁴ This low figure means that, even if the price of primary food that SSA imports from the EU falls considerably, the change in the price of composite aggregate imports of primary food to SSA will be modest in comparison.

Furthermore, when consumers and producers buy the composite imported goods, the price they face for consumption (*consumer price*, *input price*) of the goods will consist of a portion of domestic price and imported price (*consumer price for imports*, *imported input price*) of the goods.¹⁵ The price therefore depends on the relative shares of imports in their consumption basket (about 3 percent of primary food and 19 percent of processed food consumed in SSA is imported)¹⁶ and intermediate input mix, and includes domestic taxes on consumption or intermediate input use in SSA.

Besides being buyers of inputs, producers are also sellers to domestic, EU and other (foreign) consumers. To analyse the full impact on SSA producers, it is necessary to examine what happens to the prices they receive for the products they sell. As shown in Table 5 (last column, producer price), these prices fall, which is not surprising with the increase in EU output of food. As a result, SSA's exports to the EU fall while its imports from the EU increase (Table 6). The second set of numbers in parentheses in Table 6 show total SSA exports, because total exports of a food category matter to producers, and not only exports to the EU. SSA exports to the world also fall because the EU gains competitiveness in the rest of the world. Furthermore, cheaper imports compete with domestic sales of SSA producers (modest but negative impact). While consumption in SSA slightly increases because of the fall in prices, SSA producers are less able to compete with EU farmers and so produce less.

¹⁴ The corresponding share of SSA imports of processed food from the EU is 27 percent.

¹⁵ In the input price column in Table 5, two numbers show the maximum and minimum change in price of the food category in question (primary food), used as input across all sectors.

¹⁶ Numbers calculated using base year (2007) data.

TABLE 6

Impact on sub-Saharan Africa (SSA) market in 2020, agricultural food losses (AFL) scenario

Category	SSA imports from the EU	SSA exports to the EU (world)	Domestic sales in SSA	Production in SSA	Consumption in SSA
<i>Percentage difference from BaU</i>					
Primary food	20.35	-25.02 (-10.25)	-0.032	-0.41	0.06
Processed food	1.58	-2.07 (-0.92)	-0.010	-0.08	0.03
Consumed food	2.42	-9.46 (-4.37)	-0.012	-0.30	0.045
Food	3.43	-9.48 (-4.05)	-0.021	-0.25	0.047

Source: MAGNET model results.

TABLE 7

Welfare impacts in 2020, agricultural food losses (AFL) scenario

Absolute change in welfare: AFL minus BaU (change, as percentage of GDP in AFL scenario)	
<i>(2007, US\$ million)</i>	
EU	SSA
15 762 (0.08)	-144 (0.01)

Source: MAGNET model results.

Table 6 shows that SSA consumers benefit on average from food loss reductions in agricultural supply in the EU. Producers in SSA, while benefiting from a reduction in the price of imported inputs from the EU, face a reduction in the price they receive for their output in both SSA and abroad. How these effects balance out for the SSA economy as a whole can be seen from the change in welfare (measured by the equivalent variation, Table 7).¹⁷ The impact on SSA is somewhat negative – minus US\$144 million – while the EU as a region experiences a gain in welfare of US\$15 762 million. These numbers, when seen as a fraction of GDP in 2020, are negligible (less than 1 percent for all scenarios) and are reported in the parentheses, together with the absolute change in welfare.

¹⁷ The equivalent variation shows a monetary equivalent that needs to be taken away from the region for it to be as well off as in the BaU scenario.

See http://www.investorwords.com/17565/equivalent_variation.html

4.2 REDUCING PROCESSING FOOD LOSSES

SUMMARY

As food processing in the EU becomes more efficient, it is able to produce more processed food commodities while using fewer primary food commodities. This reduces demand for primary commodities and increases the supply of processed food, thus reducing the price of both commodities in the EU. EU exports become cheaper and SSA responds by importing more from and exporting less to the EU. Producers in SSA gain from a reduced price for their imported inputs but also face lower prices and sales, both at home and abroad.

As the processing sector in the EU becomes more efficient in its use of primary food commodity inputs, its output increases and demand for inputs falls. The analysis is similar to the one in the production loss reduction (AFL) scenario but, instead of all inputs in the production of primary food commodities becoming more efficient, it is the use of primary food commodities in processed food that becomes more efficient. Consequently, as discussed previously and shown in Table 8, there is a reduction in domestic demand for primary food (-0.58 percent) and a rise in output of processed food (+0.32 percent).

As apparent from Table 8, the impact on EU prices of reducing food losses at the processing stage is modest in comparison with reducing food losses in agricultural supply because of their smaller size and scope (only affecting primary agricultural inputs). The same price transmission channels are traced to see the impact of consumers and producers in SSA.

With the price of processed food in the EU falling by 0.32 percent, the export price of processed food from the EU to SSA also falls. Table 9 shows that it falls by 0.21 percent but the reduction in imported processed food prices in SSA markets is much lower (-0.08 percent), since imports of processed food from the EU constitute only a part of SSA's total imports of processed food. These prices, after adding consumption taxes, are transmitted to consumers. The final consumption price of

TABLE 8
Impact on the European Union (EU) market in 2020, processing food losses (PFL) scenario

Category	Production volume	Domestic demand	Market price
<i>Percentage difference from BaU</i>			
Primary food	-0.49	-0.583	-0.296
Processed food	0.32	0.224	-0.318
Consumed food	0.3	0.206	-0.32
Food	0.17	0.073	-0.305

Source: MAGNET model results.

TABLE 9

Price transmission to sub-Saharan Africa (SSA) in 2020, processing food losses (PFL) scenario

Category	Price of products imported from the EU	Composite price of imported products	Consumer price for imports	Consumer price	Imported input price	Input price	Producer price
<i>Percentage difference from BaU</i>							
Primary food	-0.248	-0.083	-0.073	-0.063			-0.053
Processed food	-0.211	-0.077	-0.061	-0.031	(-0.01, -0.19)	(-0.00, -0.3)	-0.017
Consumed food	-0.212	-0.093	-0.061	-0.052	–	–	-0.032
Food	-0.214	-0.08	-0.062	-0.049	–	–	-0.035

Source: MAGNET model results.

TABLE 10

Impact on sub-Saharan Africa (SSA) market in 2020, processing food losses (PFL) scenario

Category	SSA imports from the EU	SSA exports to the EU (world)	Domestic sales in SSA	Production in SSA	Consumption in SSA
<i>Percentage difference from BaU</i>					
Primary food	0.91	-0.89 (-0.05)	-0.013	-0.027	0.008
Processed food	0.86	-1.27 (-0.02)	-0.022	-0.066	0.006
Consumed food	0.86	-1.13 (-0.032)	-0.013	-0.048	0.007
Food	0.87	-1.14 (-0.035)	-0.017	-0.046	0.007

Source: MAGNET model results.

imported processed food falls by -0.06 percent and, with imported processed food consisting of only part of processed food consumption (a part of consumption is provided for by domestically produced processed food), the consumption price falls by only -0.03 percent.¹⁸

We examine, from the producers' point of view, the demand for domestically produced processed food, in both SSA and export markets (Table 10). As in the AFL scenario, SSA's imports increase and exports fall. However, note that the impacts are smaller in comparison with the case where food losses are reduced in agricultural supply. As a result, welfare impacts (Table 11) are also smaller and, as before, positive for the EU and somewhat negative for SSA.

¹⁸ Note that impacts on prices that producers in SSA pay for imported processed food are irrelevant since processed food is mostly consumed directly by households.

TABLE 11

Welfare impacts in 2020, processing food losses (PFL) scenario

Absolute change in welfare: PFL minus BaU (change, as percentage of GDP in PFL scenario)	
(2007, US\$ million)	
EU	SSA
3 565 (0.02)	-12 (0.001)

Source: MAGNET model results.

4.3 REDUCING FOOD WASTE IN RETAIL SERVICES

SUMMARY

With reduced food waste in the retail sector in the EU, demand, production and price of processed food in the EU fall. Because of these upstream links, it means that demand, output and price of primary food in the EU also fall. This enables the EU to export both primary and processed food at lower prices. SSA imports more of both commodity types at lower prices, and consumers in SSA benefit. As before, SSA producers gain from cheaper imports of intermediate inputs but lose out from falling prices and production.

This scenario involves making the retail sector in the EU more efficient mainly in its use of processed food products, as intermediate inputs. More specifically, the use of fruit and vegetables, fish and all processed food commodities in the retail sector becomes more efficient. Consequently, the retail sector demands fewer of these commodities to produce the same output or produces more, using the same amount of inputs. As a result, domestic demand and production of primary food, processed food, consumed food, food as a whole and associated market prices fall, with retail in the EU benefiting from increased efficiency in terms of lower cost and prices (-0.06 percent) and higher production and domestic sales (+0.03 percent) (Table 12).

The impact of food waste reductions in EU retail on consumers and producers in SSA would operate mainly through the impact of the price of processed food, and hence consumed food. When the retail sector becomes more efficient and reduces its demand for processed food as an intermediate input, the demand for primary food as an input into processed food production also falls.¹⁹

The change in price in European markets can be traced to its impact on consumer and producer prices in SSA in the same way as in the previous two scenarios. As shown in Table 13, the impact of food waste reduction in retail in the EU on SSA consumers and producers is relatively small. This is because the shocks in retail,

¹⁹ Note that most of the retail sector output is consumed domestically, so is irrelevant for SSA producers and consumers.

TABLE 12

Impact on the European Union (EU) market in 2020, retail food waste (RFW) scenario

Category	Production volume	Domestic demand	Market price
<i>Percentage difference from BaU</i>			
Primary food	-0.0733	-1.361	-0.0765
Processed food	-0.1166	-0.98	-0.0065
Consumed food	-0.1144	-1.058	-0.0169
Food	-0.1084	-1.007	-0.0195
Retail	0.0394	0.033	-0.0601

Source: MAGNET model results.

TABLE 13

Price transmission to sub-Saharan Africa (SSA) in 2020, retail food waste (RFW) scenario

Category	Price of products imported from the EU	Composite price of imported products	Consumer price for imports	Consumer price	Imported input price	Input price	Producer price
<i>Percentage difference from BaU</i>							
Primary food	-0.055	-0.032	-0.011	-0.013	(-0.11, -0.005)	(-0.02, -0.01)	-0.009
Processed food	-0.004	-0.002	-0.002	-0.002	(-0.003, -0.001)	(-0.003, -0.002)	-0.003
Consumed food	-0.007	-0.026	-0.002	-0.01	–	–	-0.007
Food	-0.009	-0.018	-0.002	-0.008	–	–	-0.006

Source: MAGNET model results.

which are generally relatively small, translate into smaller changes in primary, processed and (consumed) food prices in the EU. Depending on their importance for the SSA market, these then translate into impacts on SSA producers and consumers.²⁰

Finally, we examine what happens to producers as sellers of goods to consumers both in the EU and abroad (including firms and final consumption demand abroad). SSA imports still rise and exports still fall, but both are much less affected than under the previous scenarios. The same is true for domestic sales, production and consumption (Table 14). The welfare numbers also show that a 50 percent reduction in food waste in the EU at the retail stage does not have much impact on SSA (Table 15).

²⁰ In terms of shares of their total expenditure on imports from EU, consumers in SSA spend only 6 and 1 percent on processed and primary food commodities, respectively.

TABLE 14

Impact on sub-Saharan Africa (SSA) market in 2020, retail food waste (RFW) scenario

Category	SSA imports from the EU	SSA exports to the EU (world)	Domestic sales in SSA	Production in SSA	Consumption in SSA
<i>Percentage difference from BaU</i>					
Primary food	0.17	-0.14 (-0.009)	-0.000265	-0.002323	0.001470
Processed food	0.01	-0.17 (-0.003)	0.000363	-0.004912	0.001056
Consumed food	0.02	-0.16 (-0.007)	0.000455	-0.004147	0.001303
Food	0.02	-0.16 (-0.006)	0.00003	-0.003569	0.001257

Source: MAGNET model results.

TABLE 15

Welfare impacts in 2020, retail food waste (RFW) scenario (2007, million US\$)

Absolute change in welfare: RFW minus BaU (change, as percentage of GDP in RFW scenario)	
<i>(2007, US\$ million)</i>	
EU	SSA
1 602 (0.01)	-3 (0.0002)

Source: MAGNET model results.

4.4 REDUCING FOOD WASTE IN FINAL CONSUMPTION

SUMMARY

When consumers in the EU waste less food, they demand less food as they need to buy less to be as well off as before. Both demand and production of food in the EU fall. As a result, EU food prices and the price of food in SSA as an importer of food from the EU fall as well. In SSA, consumers gain from lower food prices but producers face a mixed bag of impacts: they gain as the cost of imported inputs falls but they lose as they also obtain a lower price for their food products. With increased competition from EU producers, sales of SSA food producers fall.

The consumption stage of the EU food waste reduction efforts is more straightforward. It can be interpreted as consumers in the EU wasting less and therefore (assuming that their preferences have not changed) demanding less food, including fish, vegetables, fruit and processed food.²¹ With a reduction in the demand for

²¹ See Rutten *et al.* (2013) for more background on how to model and analyse the impacts of household food waste reductions in the EU.

food, food prices in the EU fall (Table 16). The reduction in processed food demand by EU consumers leads to a fall in the demand for primary food inputs by the processed food industry. Similarly, demand for fish, vegetables and fruit falls. The overall impacts are shown in Table 16.

Again, this change in food prices is transmitted to SSA producers and consumers through trade. The change is shown in Table 17. Both consumers and producers gain from a reduction in prices of final goods and imported intermediate inputs.

In terms of magnitude (comparing scenarios), the reduction in food consumption prices that SSA consumers face is greatest in this scenario, followed by food loss reductions in agricultural supply and reductions in the processing sector; consumer prices fall the least when food waste in the EU is reduced in the retail sector. This is mainly because food waste in household demand is relatively large in the EU compared with food loss and waste in the other stages of the FSC and so the applied shocks are generally greater than in the other scenarios.

For the effect on producers as sellers of goods, the price received for all foods falls (Table 17, last column), while domestic sales do not change much (Table 18).

TABLE 16
Impact on the European Union (EU) market in 2020, consumption food waste (CFW) scenario

Category	Production volume	Domestic demand	Market price
<i>Percentage difference from BaU</i>			
Primary food	-3.094	-3.359	-2.246
Processed food	-5.82	-6.159	-0.472
Consumed food	-5.762	-6.131	-0.64
Food	-5.304	-5.634	-0.828

Source: MAGNET model results.

TABLE 17
Price transmission to sub-Saharan Africa (SSA) in 2020, consumption food waste (CFW) scenario

Category	Price of products imported from the EU	Composite price of imported products	Consumer price for imports	Consumer price	Imported input price	Input price	Producer price
<i>Percentage difference from BaU</i>							
Primary food	-1.865	-0.569	-0.4921	-0.4839	(-1.2, -0.33)	(-0.5, -0.48)	-0.4264
Processed food	-0.329	-0.153	-0.1429	-0.1504	(-0.21, -0.09)	(-0.16, -0.14)	-0.1564
Consumed food	-0.392	-0.391	-0.1558	-0.3425	–	–	-0.2733
Food	-0.502	-0.377	-0.1748	-0.3415	–	–	-0.2979

Source: MAGNET model results.

SSA producers do lose ground in their export markets because of increased competition from EU producers.

The welfare results in this scenario show that impacts are negative for the EU economy as a whole as food production lessens in response to the fall in demand (Table 19). Consumers are, however, better off in terms of lower market prices and reduced expenditures on previously wasted food. Thus, they have more to spend on other products and services and can increase their welfare. The way food waste reductions can currently be modelled implies that MAGNET does not adequately capture the gain in welfare from avoiding previously wasted food by consumers. The welfare gains for consumers are likely to be considerable, as demonstrated by Rutten (2013). Our calculations based on model results, along the lines of those reported by Rutten *et al.* (2013), show that by reducing food waste in consumption, EU consumers could save an equivalent of US\$228 per capita in 2020 (US\$116 billion in total) on food expenditure, which would translate into welfare gains for consumers. As previously discussed, these welfare numbers are quite small, in terms of a fraction of the regional GDP.²²

TABLE 18
Impact on sub-Saharan Africa (SSA) market in 2020, consumption food waste (CFW) scenario

Category	SSA imports from the EU	SSA exports to the EU (world)	Domestic sales in SSA	Production in SSA	Consumption in SSA
<i>Percentage difference from BaU</i>					
Primary food	7.09	-12.34 (-0.42)	-0.005981	-0.1783	0.0671
Processed food	0.85	-7.99 (-0.16)	-0.004845	-0.2519	0.0412
Consumed food	0.99	-9.5 (-0.27)	0.001517	-0.2694	0.0527
Food	1.46	-9.4 (-0.29)	-0.005447	-0.2137	0.0538

Source: MAGNET model results.

TABLE 19
Welfare impacts in 2020, consumption food waste (CFW) scenario

Absolute change in welfare: CFW minus BaU (change, as percentage of GDP in CFW scenario)	
<i>(2007, US\$ million)</i>	
EU	SSA
-45 564 (0.23)	-45 (0.003)

Source: MAGNET model results.

²² Note that comparing the CFW and BaU numbers in 2020 results in a negative change; if we compare the numbers over time within the CFW scenario, the welfare change is positive. In other words, EU and SSA gain in terms of welfare when they implement CFW (or FLW in general), just not as much as in BaU.

4.5 REDUCING FOOD LOSS AND WASTE IN ALL STAGES

SUMMARY

A reduction in food losses and waste in all stages of the EU FSC causes food prices in the EU to fall. Exports of food from the EU to SSA (and to other regions) become cheaper. SSA imports more food from the EU at lower prices and exports much less. Consumers in SSA are better off with lower food prices but producers are hurt from a reduction in the production of food and also from lower domestic and export prices. The EU is worse off as well since food production in EU falls because of a relatively strong and dominating reduction in domestic demand.

Having explained each stage separately, we now turn to the overall scenario where at all stages of food production/processing/distribution and consumption, food loss and waste are reduced simultaneously. From the individual cases above, consumers are expected to gain in terms of reduced food consumption prices but producers to lose from the fall in prices they are paid for their output (even though they do marginally gain from reduced prices of imported intermediate products). When comparing scenarios, reducing food losses in agricultural supply and food waste in final consumption are the two most influential scenarios in terms of the impact they have on prices in the EU and in SSA. Consequently, these scenarios explain most of the pattern of the overall scenario.

Table 20 shows the impacts of EU food loss and waste reductions on food production, demand and market prices in the EU. When these reductions occur at every stage, market price, domestic demand and output in the EU fall. When comparing the different types of food loss and waste reductions, it can be seen that prices fall in all cases. Domestic demand and production tend to increase when the food sector becomes more efficient at the agricultural supply and processing stages (Tables 4 and 8). However, domestic demand and production tend to fall when efficiency increases at the consumption and distribution stages (Tables 12 and 16). The latter effect seems to dominate.

TABLE 20
Impact on the European Union (EU) market in 2020, food loss and waste (FLW) scenario

Category	Production volume	Domestic demand	Market price
<i>Percentage difference from BaU</i>			
Primary food	-0.206	-2.116	-8.154
Processed food	-5.149	-5.742	-1.415
Consumed food	-4.665	-5.531	-2.275
Food	-4.214	-5.062	-2.72

Source: MAGNET model results.

The impacts that this overall scenario has on SSA prices are shown in Table 21. In terms of commodity groups, the most significant changes in prices are for primary food commodities, but these constitute only about 11 percent of SSA's food imports from the EU and therefore translate into much smaller impacts on consumer prices in SSA.

Focusing on SSA producers, they are disadvantaged because exports of primary food commodities fall by over 35 percent and imports increase by almost 30 percent compared with BaU (Table 22). Nonetheless, price impacts are not great (all food prices fall by less than 1 percent (Table 21, last column).

In terms of welfare (Table 23), SSA is worse off in the combined scenario than in any other individual scenario because food producers in SSA are losing ground to European producers, who are becoming more efficient in their production, processing and distribution operations; each contributing to an increased competitiveness of the EU. Consumers in SSA, however, benefit from the lower prices for both imported and domestically produced food (Table 21). For the EU, the welfare impact is approximately equal to the sum of the welfare gains from the individual

TABLE 21

Price transmission to sub-Saharan Africa (SSA) in 2020, food loss and waste (FLW) scenario

Category	Price of products imported from the EU	Composite price of imported products	Consumer price for imports	Consumer price	Imported input price	Input price	Producer price
<i>Percentage difference from BaU</i>							
Primary food	-6.745	-1.587	-1.6056	-0.9065	(-3.1,-0.9)	(-1.08,-0.9)	-0.8066
Processed food	-1.022	-0.422	-0.3782	-0.3203	(-0.5,-0.2)	(-0.36,-0.3)	-0.2882
Consumed food	-1.417	-1.097	-0.4385	-0.6303	–	–	-0.4964
Food	-1.767	-1.049	-0.4921	-0.6562	–	–	-0.5616

Source: MAGNET model results.

TABLE 22

Impact on sub-Saharan Africa (SSA) market in 2020, food loss and waste (FLW) scenario

Category	SSA imports from the EU	SSA exports to the EU (world)	Domestic sales in SSA	Production in SSA	Consumption in SSA
<i>Percentage difference from BaU</i>					
Primary food	29.93	-35.21 (-0.80)	-0.054793	-0.575	0.1361
Processed food	3.36	-11.15 (-0.29)	-0.040134	-0.397	0.0796
Consumed food	4.39	-18.97 (-0.49)	-0.02623	-0.590	0.1040
Food	5.98	-18.91 (-0.56)	-0.047904	-0.489	0.1071

Source: MAGNET model results.

TABLE 23

Welfare impacts in 2020, food loss and waste (FLW) scenario

Absolute change in welfare: FLW minus BaU (change, as percentage of GDP in FLW scenario)	
(2007, US\$ million)	
EU	SSA
-25 549 (0.13)	-171 (0.01)

Source: MAGNET model results.

TABLE 24

Welfare impacts by sources in 2020

	AFL		PFL		RFW		CFW		FLW	
	EU	SSA	EU	SSA	EU	SSA	EU	SSA	EU	SSA
Absolute change from BaU										
(2007, US\$ million)										
Allocative efficiency	138	41	-45	9	-114	1	-25 067	74	-24 995	126
Terms of trade	-223	-42	45	-6	24	-2	-2 906	-7	-3 235	-36
Technical	15 597	-66	3 481	-11	1 654	-1	-11 852	-70	8 052	-144
Other	250	-77	83	-6	39	-1	-5 740	-42	-5 370	-118
Total	15 762	-144	3 565	-12	1 602	-3	-45 564	-45	-25 549	-171

Source: MAGNET model results and authors' calculations.

scenarios of reducing agricultural food losses (+US\$15.7 billion); loss reductions in food processing (+US\$3.5 billion) and food waste reductions in retail services (+US\$1.6 billion); and the welfare loss reported from reducing food waste in final consumption (-US\$45.5 billion). The latter figure excludes welfare gains from reducing previously wasted food.

Finally, a welfare breakdown of the scenarios demonstrates that the major sources of change in welfare are technical, terms of trade and allocative efficiency changes. As well as showing the change in total welfare, Table 24 shows changes in these three components for each of the scenarios.

Allocative efficiency changes involve gains or losses coming from redistribution of factors of production and production in economy, and their interaction with taxes and subsidies already present in the economy. Note that these efficiency gains for SSA are always positive, since SSA gains from importing food from EU and releasing the factors of production tied up in domestic food production for more productive uses in SSA. For the EU, the allocative efficiency changes are positive only in the AFL scenario when all factors of production become more efficient. In the other scenarios, only some inputs become more efficient – others do not.

Together with inherent distortions in the EU economy, this yields negative contribution to welfare.

Contributions from technical change alone in the EU are always positive, as expected, except in the CFW scenario. In this scenario, these changes actually represent the reduction in value added in the food sector because of lower consumption demand in the EU.

The negative terms of trade results for the EU show the reduction in export price that the EU obtains, while for SSA they represent the increasing imports (and lower exports) from the EU.

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Chapter 5

Discussion

The empirical exercise used FAO data to model the impacts of food loss and waste reduction in the EU on food prices in SSA and shows how these are transmitted. Four reduction scenarios were implemented in the MAGNET model in addition to a baseline BaU scenario, as detailed in Chapter 3 and summarized in Table 3.

- *Scenario 1.* Agricultural food losses (AFL) in supply modelled a reduction of 50 percent in the EU of food loss for all primary agricultural commodities (cereals, vegetables and fruit, oilseeds and pulses, cane and beet crops, livestock including cattle and chicken, raw milk and fish).
- *Scenario 2.* Processing food losses (PFL) comprised a 50 percent reduction in the EU of food losses in processed rice, sugar, meats, vegetable oils and fats, dairy products and other food and beverage products.
- *Scenario 3.* Retail food waste (RFW) included a 50 percent food waste reduction in the EU for all processed foods, fish and fruit and vegetables (otherwise part of primary food commodities), as they are used by retail.
- *Scenario 4.* Final consumption food waste (CFW) applied negative taste shocks that target a 50 percent reduction in EU food waste in final consumption, with household demand for food commodities or products falling accordingly.
- *Scenario 5.* Overall food loss and waste (FLW) combined all scenarios for an analysis of effects of food loss and waste reductions in the EU by segment of the FSC.

The shocks were analysed based on four dimensions: (i) impacts on the EU market in 2020; (ii) price transmission to SSA in 2020; (iii) impacts on the SSA market in 2020; and (iv) welfare impacts in 2020. In terms of reporting, food commodities were grouped into four categories that are potentially impacted, namely primary food, processed food, consumed food and a broader food category comprising both primary and processed food (see Chapter 4).

All four scenarios show a decrease in market prices because of the reduction of 50 percent in food loss and waste in the EU. The greatest impact in EU market price reductions is in the aggregate scenario (Table 20), closely followed by the AFL supply scenario (Table 4) and CFW scenario (Table 16), within which individual commodities vary in the magnitude of their price decrease. The extent of market price decreases for EU primary producers (Tables 4, 8, 12, 16, 20) is shown within the range of -0.07 (in the RFW scenario) to -8.15 (in the FLW scenario) while modelled impacts on primary producers' prices (Tables 5, 9, 13, 17, 21) illustrate a decrease from -0.009 (RFW) to -0.80 (FLW) for SSA because of price transmission. In all scenarios, price transmission is less than 100 percent because of import and export taxes, transport costs and trade shares (Sections 3.3, 3.4, 4.1 and Appendixes).

The most important stages in the EU FSC in terms of impacts of food loss and waste reductions on SSA prices are those of final consumption, followed by agricultural supply. Reductions in food waste in final consumption and food losses at the primary agricultural production stages are relatively large and thus have a much stronger price impact in SSA compared with food loss and waste reductions in the other segments of the EU FSC. Geographically, the effects are highest in the region where action is taken to reduce FLW, *ceteris paribus*, with the impact on the other regions depending on trade intensities (shares) and the relative importance of traded food commodities in domestic food consumption.

On aggregate, the results suggest that, *ceteris paribus*, reducing food loss and waste in the EU does not benefit SSA. This outcome is the result of different, i.e. positive and negative, impacts on various actors in the SSA economy. These are:

- producers as sellers to the EU losing out from increased competition from EU food producers;
- producers as buyers of intermediate agrifood inputs from the EU benefiting from lower prices and consequent lower costs; and
- consumers of food commodities from the EU benefiting from lower prices.

Welfare losses for SSA are nonetheless modest and represent only a negligible fraction of GDP. Specifically, welfare losses for SSA by 2020 would amount to an annual current US\$191.5 million in total when the EU reduces food losses and waste by 50 percent in all segments of the supply chain.²³ On the other hand, the EU records welfare gains when reducing food losses and waste in agricultural supply, processed food and retail services, which outweigh welfare losses for SSA and suggest that the latter could receive compensation. Specifically, annual EU welfare gains at these stages by 2020 would amount to a current US\$24 billion in total (current US\$47 per capita). These welfare results, however, do not take into account potential costs involved in reducing FLW and therefore provide an upper boundary on welfare impacts.

The outcomes are based on the assumption that nothing else changes (the *ceteris paribus* condition). Naturally, it may well be that action is taken by SSA to cope with the price decreases they face for agrifood products. These could lie in the area of trade measures and domestic policy support for farmers. Another avenue of action is to tackle the food losses in SSA that are high. In fact, this has already been considered in the recent Malabo Declaration by African Union Heads of State and Government committed in 2014, which has as one of its objectives the target of halving current levels of post-harvest losses by 2025.²⁴ If these actions are to

²³ Using a conversion factor of 1.15, based on the percentage increase in the consumer price index recorded over the period 2007 to 2014 (<http://data.bls.gov/cgi-bin/cpicalc.pl>)

²⁴ Furthermore, food loss and waste reduction are being tackled at the global level through the Zero Hunger Challenge. This vision applies a sustainable food systems approach with the aim of zero food loss and waste. The Committee on World Food Security (CFS), the world's foremost inclusive inter-governmental and multistakeholder platform for food security and nutrition, at its Forty-first Session on "Making a difference in food security and nutrition", called on all concerned stakeholders to undertake cost-effective, practicable and environmentally sensitive actions according to their priorities and means to reduce food loss and waste. Additionally, food loss and waste reduction and monitoring are being discussed for the Post-2015 Development Agenda within potential Goal 12 on ensuring sustainable consumption and production patterns.

take place concurrently with actions in the EU, the observed effects on prices and welfare are likely to differ from those reported in the above sections. These potential policy responses, each with their own costs and benefits, could be the subject of further research.

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Chapter 6

Conclusions

Results show that reducing food loss and waste in the EU can be beneficial in reducing food prices, which has differential impacts across producers and consumers in the EU and SSA, and the underlying mechanisms that play a role. Overall, SSA experiences welfare losses, but these are a fraction of the economy. This outcome is the result of different, i.e. positive and negative, impacts on various actors in the SSA economy, including impacts on producers as sellers losing out from increased competition from EU food producers; producers as buyers of intermediate agrifood inputs from the EU benefiting from lower prices and so lower costs; and consumers of food commodities from the EU benefiting from lower prices. The effects are highest in regions where action is being taken to reduce food loss and waste, i.e. the EU, thus providing a compelling argument for policy-makers wanting to tackle high food prices to enact plans/actions in their respective regions and/or countries to reduce food losses and waste.

However, the complex interactions between supply and demand shifts arising from food loss and waste reduction illustrate that it is difficult to predict the potential socio-economic impacts of such actions, especially in a world that is continuously and rapidly changing, and that trade-offs are likely to occur. They nonetheless provide useful insights into what may happen, and provide a useful starting-point for further and more complex foresight analysis of what the world may look like in 2020 and beyond.

Further research is foreseen regarding improving the methodology of analysing impacts of food loss and waste (reductions) and regarding the scope of the study. Methodologically, further work is required in the following areas. First, food loss and waste should be incorporated explicitly in the modelling of the food system, preferably as endogenous outcomes or activities that have returns and costs, so that underlying causes and measures to tackle food loss and waste, and associated costs can be modelled. Second, short-term impacts may be analysed by adjusting the model for market rigidities/imperfections that result in more vehement price changes. Third, if interested in distributional impacts, the model needs to be adapted to include different types of households to account for differential welfare impacts across net food consumers and net food producers (work in progress).

Regarding the scope of the study, further research should look into the impacts of food loss and waste reductions at the global level (considering impacts for all regions of the world) and should look beyond pure economic impacts to include, for instance, environmental and health impacts. These improvements would allow for an integrated systemic view in order to move to a new equilibrium with less food loss and waste. In fact, the approach of many countries and local initiatives has been to encourage behavioural change beyond economics and consider a short-, medium- and long-term integrated perspective.

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Appendix 1

Non-technical summary of the MAGNET model

GTAP CORE

Household behaviour is captured via a “representative regional household” which, in searching to maximize its utility, collects all income generated in the economy and allocates it over private household and government expenditures on commodities, and savings for investment goods. Income comes from payments by firms to the regional household for the use of endowments of skilled and unskilled labour, land, capital and natural resources. The regional household also receives income from (net) taxes paid by the private household (on private consumption and income), firms (taxes on intermediate inputs and production) and the government (on its expenditures).

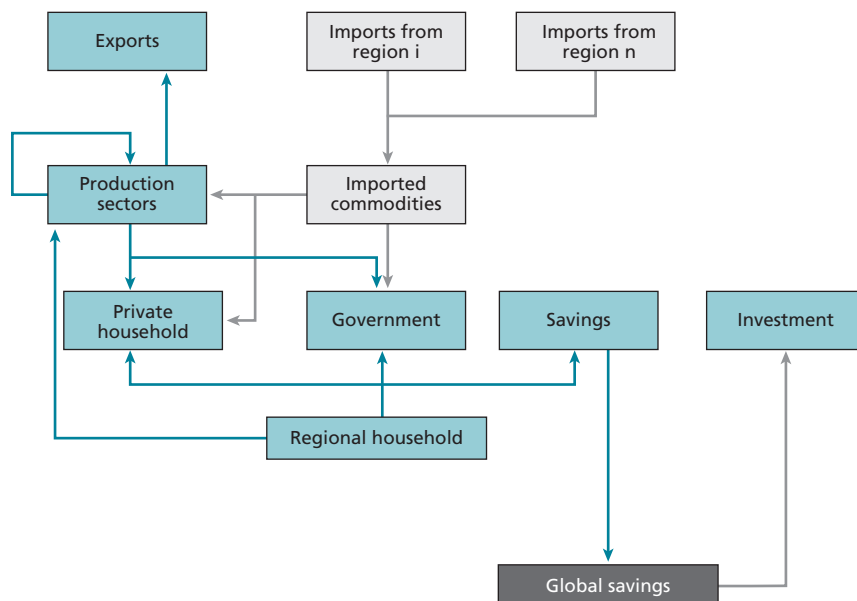
Firms, in searching to maximize profits, produce commodities by employing the aforementioned endowments and intermediate inputs from other firms using a “constant return to scale” production technology²⁵ so as to sell them to private households, the government and other producers. Regarding *trade*, domestically produced goods can be sold either on the domestic market or to other regions in the world. Similarly, domestic intermediate, private household and government demand for goods can be satisfied by domestic production or by imports from other regions in the world (“Armington assumption”). These come with their own import and export taxes. Sourcing of imports happens at the border, after which – based on the resulting composite import price – the optimal mix of import and domestic goods is derived.²⁶ Demand for and supply of commodities and endowments meet in *markets*, which are perfectly competitive and clear via price adjustments. *Natural resources* are assumed to adjust sluggishly between sectors. The assumptions regarding the land, capital and labour markets are discussed below.

With all markets in equilibrium, firms earning zero profits and households being within their budget constraint, global savings must equal global investments. Investments are computed on a global basis, via a “global bank” that assembles *savings* and disburses *investments*, so that all savers in the model face a common price for the savings commodity. Global savings determine global investments, i.e. the *macroclosure* is savings driven and essentially neoclassical in nature. Since GTAP is basically a comparative static model, investments only influence the pattern of production

²⁵ This means that as firms grow, they do not become more efficient or less efficient.

²⁶ The Armington assumption implies that an increase in the domestic price relative to imports will lead to an increase in demand for imports relative to domestic goods. Similarly, if imports from one source country become more expensive, there will be substitution towards imports from another cheaper source country.

FIGURE 3
A simplified representation of the Global Trade Analysis Project (GTAP) model



Source: Woltjer et al., 2014 (adapted with permission).

(via investments as a demand category) and are not installed to add to the productive capacity of industries over time. As the CGE model can only determine *relative prices*, the GDP deflator is set as the “numéraire” (i.e. the basic unit to represent value) of the model, against which all other prices are benchmarked. Changes in prices resulting from the model simulations thus constitute real price changes.

MAGNET EXTENSIONS

The *production structure* specified in MAGNET accounts for the inherent difference in the ease of substitution between value added and intermediates (assuming constant coefficients, i.e. no substitution) and land and non-land factors of production (little substitution between land and non-land factors, and relatively more substitution between non-land factors). The *consumption structure* specified in MAGNET allows for a better depiction of changes in diets observed over time (towards meat, dairy, fish and away from staple foods). This is achieved by updating the income elasticities in MAGNET as a decreasing function of real GDP per capita as economies grow over time, which avoids unrealistically high consumption of food items in fast growing economies.

The *segmented factor markets specification* in MAGNET divides the market for capital, skilled and unskilled labour into an agricultural and non-agricultural mar-

ket. Within each of these markets, there is perfect movement, but it is more difficult to move from one to another. This results in, for example, differences in wages levels for unskilled labour in agriculture compared with non-agriculture (i.e. industry and services sectors), which are observed in reality.

Finally, the *land market specification* in MAGNET incorporates endogenous land supply, whereby overall land supplied to (and used in) agriculture positively depends on a land price (the average of all land rental rates). The general idea underlying the land supply curve specification is that the most productive land is taken into production first. However, the potential for bringing additional land into agriculture is limited. The shape of the land supply function is governed by an asymptote, the maximum amount of land that is potentially available for agriculture, and a price elasticity of total land supply (and use). Closer to the asymptote the land price will increase by more as land use increases as it becomes relatively scarce.

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Appendix 2

Drivers of international price transmission

Factors influencing international price transmission can generally be grouped into the following main categories (FAO, 2004; Bekkers *et al.*, 2013; Siddig and Grethe, 2014).

TRANSPORT MARGINS AND TRANSACTION COSTS

Transaction costs are not included in the model. Generally, world price pass-through is more significant for domestic producers than consumers because of transport, distribution and retail costs that insulate volatility in commodity prices at the final consumption level (Bekkers *et al.*, 2013). In developed countries, with more developed FSCs, this is more so than in developing countries. The poor in developing countries, who spend a relatively large share of their income on staple foods, are thus relatively more vulnerable to changes in world market prices of food. Domestic margins are not explicitly modelled, although they are included to some extent in the trade services/retail sector. International transport margins are captured by the global transport sector (see Figure 1).

MARKET STRUCTURE

Increasing returns to scale, often in combination with market power, causes some actors to be price takers and some actors to be price setters, depending on the degree of concentration (FAO, 2004). If food suppliers have market power, they are likely to follow production cost increases, whereas production cost decreases may be absorbed by higher mark-ups. By nature of the model, we abstract from increasing returns to scale/market power.

PRODUCT DIFFERENTIATION

The more homogeneous a product across markets, the higher the degree of price transmission. The model differentiates between domestically produced and imported agrifood commodities via the Armington specification. The higher the degree of substitutability between domestic and imported commodities, the higher the degree of world to domestic price transmission since substitution towards domestic commodities increases domestic demand more easily.

EXCHANGE RATE

Since international food prices are denominated in dollars, changes in the exchange rate affect domestic prices (Bekkers *et al.*, 2013). This is not an issue in the model since all prices are denominated in dollars.

BORDER AND DOMESTIC POLICIES

Tariff and non-tariff barriers directly and indirectly create a wedge between world and domestic prices. While non-tariff barriers are not included in the model, taxes and tariffs are included *ad valorem* (see Figure 1) and so behave as a proportional transaction cost or margin (FAO, 2004).

ECONOMIC CHARACTERISTICS

Siddig and Grethe (2014) distinguish a few other factors, which can more or less be grouped as structural characteristics of the economy. First, trade shares (import and export), value-added share in the economy and share in domestic factor use matter: the more important a commodity in trade or the domestic economy, the higher the degree of price transmission from world to domestic markets. Moreover, if factors are relatively inelastic and in short supply (e.g. land), the degree of price transmission will be higher as production costs would increase by relatively the same. Second, these authors argue that not only Armington elasticities, but all production elasticities (e.g. between value added and intermediate inputs and within these categories) matter since higher elasticities imply more opportunities for producers to absorb price shocks domestically. Third, smooth factor mobility will dampen price changes and so reduce the extent of price transmission.

Potential **impacts** on **sub-Saharan Africa** of reducing **food loss** and **waste** in the **European Union**

**A focus on food prices and
price transmission effects**

This paper uses scenario analyses to investigate how reductions in food loss and waste (FLW) in the European Union (EU) could influence prices in sub-Saharan Africa – as a source and destination of traded agricultural and food products. In addition to a baseline “business as usual” (BaU) scenario, four scenarios with 50-percent reductions are enacted using the Modular Applied GeNeral Equilibrium Tool (MAGNET).

The analysis provides insights on potential impacts in terms of medium- to long-term global and local price changes in sub-Saharan Africa and the mechanisms behind them – changes in production, consumption and trade patterns. It also provides insights into the potential welfare impacts.

The research shows that loss or waste of safe and nutritious food for human consumption is being prevented and reduced in the EU concurrent to actions in other regions. The potential intra- and inter-regional impacts on food prices and welfare therefore need to be further researched and projected.

The research also shows that high-level considerations of the socio-economic impacts of FLW need to be balanced with value chain analyses that include data on costs related to the prevention and reduction measures to be implemented for short-, medium- and long-term returns on investments along food supply chains, including at the end consumption level.

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