Impacts of Reducing Global Food Loss and Waste on Food Security, Trade, GHG Emissions and Land Use

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Abstract

With global population slated to increase by another 2 billion persons by 2050 combined with agriculture's existing pressure on natural resources and responsible directly and indirectly for a significant percentage of annual greenhouse gas emissions, reducing the level of losses and wastes in the agro-food complex—from field through to final consumers—would be one option to help reduce the pressures on resources and eliminate hunger. Gustavsson et al. (2011) have estimated these losses and wastes to be on the order of magnitude of 33 percent of agricultural production—with significant differences in their sourcing across countries and regions. It is estimated that 30 to 40% losses occur in developing countries and, therefore, measures to avoid this will have a big effect on food security and food safety. (Engstrom and Carlsson-Kanyama, 2004; Kader, 2005). Furthermore, global food wastage ranks as the third top methane emitter after China and the United States by causing 3.3 Gigatonnes of CO_2 equivalent methane emissions (FAO, 2013a). Thus there is considerable potential scope for reducing food losses and wastes and its impacts on global food security and global greenhouse gas emissions. In this paper, we investigate the impacts of reducing global food loss and waste on food security, international trade, GHG emissions and land use. For this purpose, we employ the Simplified International Model of agricultural Prices, Land use and the Environment (SIMPLE).

Key Words: Global food wastes, Post-harvest crop losses, Long run global partial equilibrium

1 Introduction

Food supply must significantly increase in order to meet the future demand for food which is expected to increase significantly as a result of growing population, per capita income, and biofuel crop use. There are two options, which are not mutually exclusive, to meet this increasing demand for food in the future: (1) increasing food production; and (2) decreasing food losses and waste. Although the main focus of the literature is on the former option, the magnitude of loss and waste is too large to be ignored. Gustavsson et al. (2011) have estimated that one-third of global food produced for human consumption is lost or wasted, which is about 1.3 billion tons of food per year. On the other hand, Engstrom and Carlsson-Kanyama (2004) and Kader (2005) have estimated that 30 to 40% losses occur in developing countries and, therefore, measures to avoid this will have a big effect on food security and food safety. Finally, global food wastage ranks as the third top methane emitter after China and the United States by causing 3.3 Gigatonnes of CO_2 equivalent methane emissions (FAO, 2013a). Therefore, there is considerable potential scope for reducing food losses and wastes and its impacts on global food security and global greenhouse gas emissions.

In this study, we distinguish the food *losses* and *waste* and follow FAO's food loss and waste definitions (see FAO, 2013b). Namely;

> "**Food Loss** refers to food that during its movement along the food supply chain gets spilled, spoilt or otherwise lost or incurs reduction of quality before it reaches its final product or retail stage. Food loss is the unintended result of the process or the institutional/ legal framework.
>
> **Food Waste** refers to food that moves through the food supply chain up to a product fit for human consumption, but is not consumed because it is discarded, whether or not after it is kept beyond its expiry date or left to spoil. Food waste is the result of negligence or a conscious decision to throw food away."

Food "waste" is mainly related to consumer behavior and they mostly occur in medium/high-income countries. It is mainly because per capita income is high and hence the opportunity cost of time is low in medium/high-income countries. When the low cost of food as in the US is included

to this dynamic, it is not surprising to have 40% food waste in the U.S. (Hall et al., 2009). Food "losses", on the other hand, mostly occur in low-income countries and they are mainly related to financial, managerial, and technical limitations in harvesting techniques, storage and cooling facilities. Per capita food "wasted" by consumers in Europe and North-America is 95-115 kg/year, while this figure in sub-Saharan Africa and South/Southeast Asia is only 6-11 kg/year. Furthermore, the per capita food "loss" in Europe and North-America is 280-300 kg/year. In Sub-Saharan Africa and South/Southeast Asia it is 120-170 kg/year (see Gustavsson et al., 2011).

In the literature, Rutten and Kavallari (2013) is the only study we are aware of that empirically investigates the impacts of an abatement in food losses. Specifically, in that paper Rutten and Kavallari use the MAGNET model, which is a multi-region, multi-sector computable general equilibrium model based on the GTAP data base, to assess the impacts of reductions in agricultural food losses in the MENA region on food security. The authors take into account only pre-harvest losses and ignore post-harvest losses (losses in processing and packaging, losses in distribution), and food waste in demand side. In the model, abatement in food loss is assumed to be through total factor productivity changes. Because of the absence of reliable and consistent evidence on cost of food loss abatement, the authors assume that reducing food losses is costless. Thus, their results provide an upper bound on potential of food loss abatement on food security in the MENA region. While a useful first step, this does not provide us with much guidance for the present study.

The main motivation of this paper is to investigate the impacts of reducing global food loss and waste on food security, international trade, GHG emissions and land use. For this purpose, we employ the Simplified International Model of agricultural Prices, Land use and the Environment (SIMPLE). Historical projections from SIMPLE regarding global crop production, area, yield and prices have been validated at global scale (Baldos and Hertel, 2013) and the model has also been used in studies focusing on climate change mitigation and adaptation (Lobell et al., 2013) as well as long run food security analysis (Baldos and Hertel, 2014). In next section, we discuss our methodology about how food loss and waste are implemented into the SIMPLE model.

2 Methodology

To investigate impacts of food loss and waste mitigation on global food security and global greenhouse gas emissions we employ the Simplified International Model of agricultural Prices, Land use and the Environment (SIMPLE), documented by Baldos and Hertel (2013). SIMPLE is a partial equilibrium model with 15 regions and 4 sectors: crops, livestock, processed food, and non-food sectors. (See Table A1 in the appendix for regional mapping.) SIMPLE is designed to facilitate analysis of the drivers behind the long run supply and demand for land in agriculture. Commodity demand are characterized in terms of an "ad hoc" demand system, wherein food and non-food commodities are considered. Food consists of crops, livestock and processed food commodities. Crop use include crops consumed as food, as feedstock in global biofuel production and as inputs in the livestock and processed food industries. Production of livestock and processed food which occurs in each demand region uses crop and non-crop inputs.

The global supply of crops is based on production in 7 geographic regions, each with a different crop production function which combines land and non-land inputs to produce a homogeneous crop output. The supply of cropland varies by region and is a function of cropland returns in that geographic region, as well as land supply shifters capturing the impact of competing uses of land, including urbanization and environmental requirements. The supply of non-land inputs is more price elastic and reflects the composite supply of labor, capital and purchased materials to the crops sector.

In general, production functions for livestock, processed foods and crops follow the constant elasticity of substitution framework. However, Leontiff production is imposed in the processed food industry. There is a single global price for crops which adjusts to equilibrate global supply and demand for crops. For other commodities, market equilibrium occurs at a regional level. As a consequence, processed food, livestock and non-food products have unique regional prices.

The original model is modified in two steps to introduce food loss and food waste to the model. The following subsections describe how it is done.

2.1 Implementation of Food Loss to SIMPLE

In this approach, a new sector, called “Post-Harvest Sector”, and its input, called “Post-Harvest Input”, are introduced to the model. The outputs of crop and livestock sectors are processed with the post-harvest input in this new sector before they go to the market. During that processing some of the outputs are lost. Post-harvest input can be used to reduce those losses. Zero post-harvest input means zero precaution is taken to reduce post-harvest losses. In this approach, food loss is implicitly introduced to the SIMPLE. The activities of the post-harvest sector are assumed to be represented by a constant elasticity of substitution (CES) function (see Figure 1).

2.2 Implementation of Food Waste to the SIMPLE

In this approach, food waste is implicitly introduced to SIMPLE (see Figure 1). By introducing a new function, called “Household Production Function”, household labor and food purchases are combined to produce food consumed and the difference between the food purchased and the food consumed becomes food waste. To reduce food waste in each household, either price of food can be taxed, or household labor can be subsidized. Since food waste is implicit in the model, it cannot be taxed directly. However, this does not bring any disadvantage to the modeling because it is not possible to determine food waste of each household and tax that waste. Even it is possible, transaction cost of determination of food wastes would be significantly high.

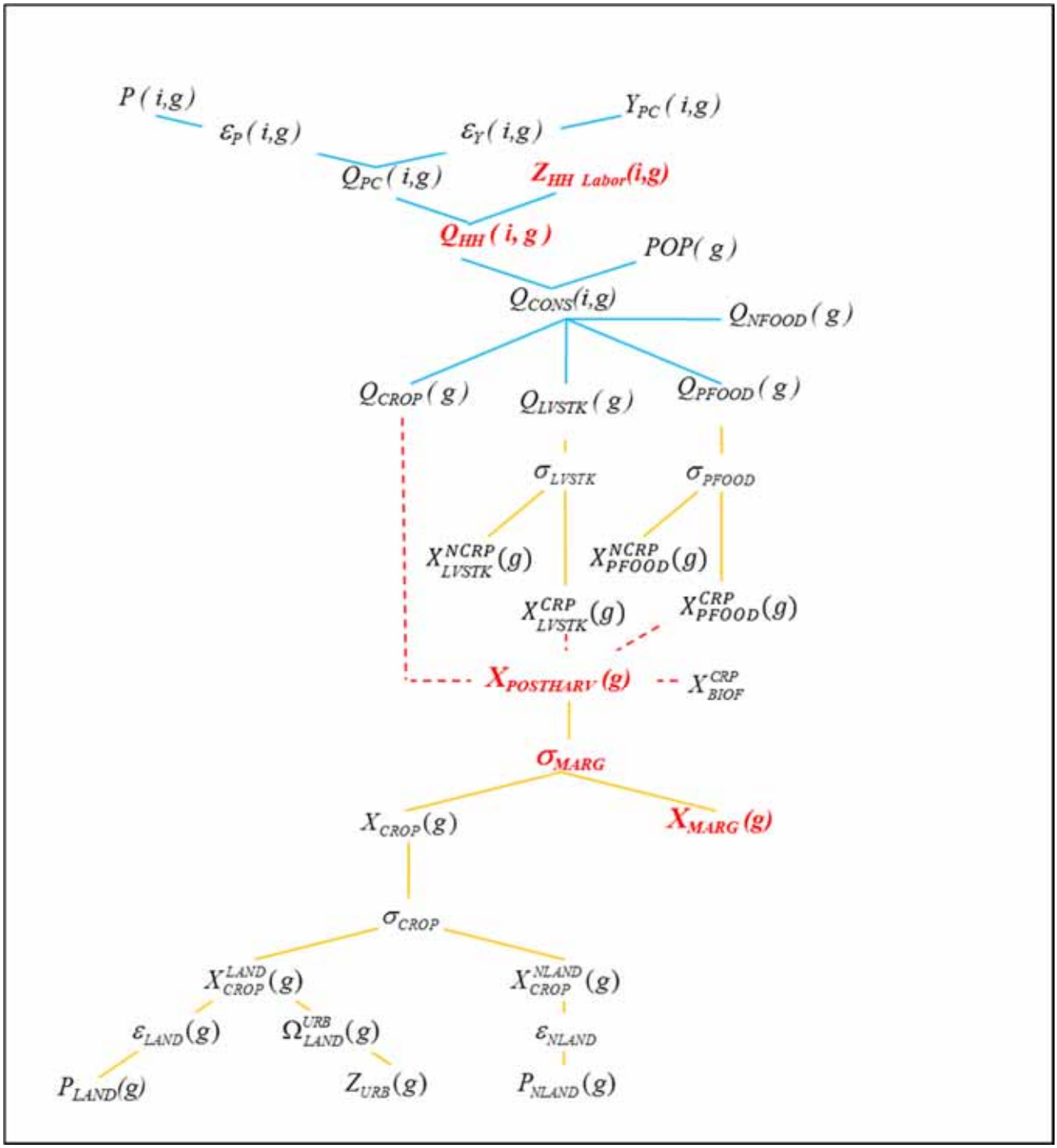

Figure 1: Structure of new SIMPLE

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Appendix

Table A1: Regional Mapping

	Code	Region	Countries
1	E_Euro	Eastern Europe	Albania, Armenia, Azerbaijan, Belarus, Gerogia, Kazakhstan, Moldova, Romania, Russian Federation, Ukraine, Yugoslavia-former.
2	N_Afr	North Africa	Algeria, Egypt, Libya, Morocco, Tunisia
3	RoAfr	Rest of Africa	Angola, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo Rep., Congo, DR, Côte d'Ivoire, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Tanzania, Togo, Uganda, Zambia, Zimbabwe
4	S_Amer	South America	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela
5	AUS_NZ	Australia/New Zealand	Australia, New Zealand
6	EU	European Union+	Austria, Bulgaria, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, United Kingdom, Belgium-Luxembourg, Czechslovakia - former
7	S_Asia	South Asia	Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka
8	CC_Amer	Central America & the Caribbean	Belize, Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Guyana, Haiti, Honduras, Mexico, Nicaragua, Panama, Puerto Rico, Suriname, Trinidad and Tobago
9	S_Afr	Southern Africa	Botswana, Lesotho, Mauritius, Namibia, South Africa, Swaziland
10	SE_Asia	Southeast Asia	Cambodia, Fiji, Indonesia, Laos, Malaysia, Papua New Guinea, Philippines, Solomon Islands, Thailand, Timor Leste, Vanuatu, Viet Nam
11	CAN_US	Canada/US	Canada, United States
12	CHN_MNG	China/Mongolia	China, Mongolia
13	M_East	Middle East	Iran, Iraq, Israel, Jordan, Lebanon, Oman, Saudi Arabia, Syria, Turkey, United Arab Emirates, Yemen
14	JPN_KR	Japan/Korea	Japan, Korea Republic
15	C_Asia	Central Asia	Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan