Enhancing Global Sustainability

by Reducing Food Waste:

Articulating and Assessing the Economic Challenges*

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Abstract:

Reducing food waste is one potential avenue for helping to sustainably nourish 9 billion people by mid-century. In this paper, we review the literature concerning food waste and assess the economic incentives surrounding food waste faced by different participants within food systems, such as food producers in developing countries, retailers in mature supply chains, and the households who purchase and prepare food provided by these retailers. We also discuss the potential for a rebound effect from exogenous improvements that reduce food waste, which, to our knowledge, has not been addressed before. Finally, we summarize and discuss several possible policies that could be considered to better manage food waste sustainably.

Keywords: food waste, food loss, over-nutrition, rebound effect, sustainability

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1. Introduction

One of the greatest challenges in the 21st century is to feed 9.3 billion people by 2050 without exacerbating global environmental degradation (World Bank, 2008; Baulcombe, 2009; Foley et al., 2011). Indeed, food production is a major driver for global environmental changes due to increased competition for resources, release of greenhouse gases, soil degradation and loss of biodiversity (Grizzetti et al., 2013; Godfray et al., 2010; Tilman et al., 2011). However, roughly one-third of all edible food is wasted annually(Gustavsson et al., 2011), suggesting an important frontier for locating food needed to sustainably nourish a growing global population. In the United States alone, the estimated total value of food loss in 2008 is $165.6 billion, which means 124 kg (273 lb) of food valued at $290 retail price was wasted from human consumption per capita per year(Buzby & Hyman, 2012).

There is an urgent need to better understand the causes of food waste, possible methods to prevent the waste, and sustainable ways to manage wasted food. Previous reviews comprehensively summarize the food waste in supply chains from a global perspective, estimate food loss and household food waste in different countries, and estimate the types of food being wasted (Parfitt et al., 2010). The present review focuses on the incentives of food waste from different agents with food systems, such as food producers in developing countries, retailers in mature supply chains, and the households who purchase and prepare food provided by these retailers. We also analyze the rebound effect of food waste, which, to our knowledge, has not been addressed before. Finally, we summarize and discuss several possible policies that could be considered to better manage food waste sustainably.

2. Definitions of Food Waste

Food waste could be defined from two perspectives. The first defines food lost in the supply chains, while the other defines it by the purpose of food.

1) Food loss in the supply chains includes the following.

a. Postharvest loss refers to measurable quantitative and qualitative food loss during the entire postharvest system(Lucia & Assennato, 1994), which includes the times from harvest to processing, transport, resale, food preparation and being eaten or discarded by consumers(Hodge, Buzby & Bennett, 2011).

b. Food loss represents the edible amount of food available for human consumption that is not consumed(Bloom, 2010), which usually take place at production, postharvest

and processing stages.

c. Food waste focuses on the food unconsumed due to the behavior of retailers and consumers, which occurs in the latter part of the supply chains.

Food loss relates to systems that require investment in infrastructure and technology, and therefore is a principal problem in developing countries. Food waste, on the other hand, mainly relates to human behavior, and is more associated with developed countries (Parfitt et al., 2010).

2) Definitions of food waste by the purpose of the food include the following.

a. Food waste is all the material edible for human consumption that is discarded, lost, or degraded by humans or consumed by pests (FAO, 1981).

b. Another definition is similar to (a), but includes edible food that could have fed to animals or is a by-product of food processing diverted away from the human food chain (Stuart, 2009).

c. A third definition is similar to (a) and (b), but includes over-nutrition, the gap between energy intake and the energy needed to maintain consistent, health body weight (Smil, 2004a).

In this paper, we refer food waste as food loss in the production, postharvest, and processing stage, food waste in the retailers and households, and over-nutrition. Food loss and food waste in the supply chain is the food physically wasted, while the food waste in term of over-nutrition is the food wasted by human bodies.

3. Food Waste: externalities and opportunity cost

Food production is a major driver for global environmental changes due to increased competition for resources, release of greenhouse gases, soil degradation and loss of biodiversity (Grizzetti et al., 2013; Tilman et al., 2011). Nearly 70% of global freshwater withdrawals are used for irrigation (Postel et al., 1996). 37% of the earth's land surface is occupied by agricultural lands, and 70% of the grassland, 50% of savanna, 45% of the temperate deciduous forest, and 27% of the tropical forest biome is cleared or converted by agricultural (Pretty, 2008). 52% and 84% of global anthropogenic methane and nitrous oxide (Smith, 2008), which are more damaging than carbon dioxide (Godfray et al., 2010), is emitted during the food production process. If the food is wasted, a great amount of money, resources, and labor are wasted and considerable negative externalities are generated during its lifecycle. Furthermore, much of wasted food will be disposed in landfills instead of being used as animal feed or compost, especially in developed countries. As a consequence, much methane and carbon dioxide will be produced during its decomposition and large areas will be needed for landfilling. According to a study in the UK, 3% of greenhouse gas emission is from the waste sector, where nearly half is associated with food waste (DEFRA, 2011; Papargyropoulou, 2014). The area dedicated to landfills also intensifies global competition for land.

4. Waste Prevention

4.1 Food waste in developing countries

Food losses mostly take place in developing countries. More than 40% of food post-harvest or during processing is lost because of poor infrastructure and technological conditions (FAO, 2011). Perishable food like fruit, vegetables, meat and fish can easily deteriorate when appropriate storage, cooling, and transportation infrastructures are absent. For example, in India alone, 35-40% of fresh food is lost due to the lack of cold storage. Many simple technologies, however, are available to reduce these kinds of loss. For example, an FAO project in Afghanistan dramatically reduced food losses just by providing sealed storage drums for grain farmers (FAO, 2008).

Some farmers might choose to harvest and sell food at inappropriate times, which results in considerable food waste. For example, liquidity constrained farmers without short-term credit options may harvest foods too early to sell for cash despite discounts for poor quality from immaturity and decreased yield from premature harvest. Likewise, liquidity and credit constrained farmers may sell for cash at harvest into a saturated market rather than store product for later delivery at higher prices. In this way improve rural credit may help alleviate food loss in developing country contexts.

Furthermore, in developing countries, the integration of producer, suppliers, and processors across the food value chain may be uneven. As a result, food produced by farmers may not reach consumers in an efficient way. Food may be wasted during the long journey from farmers to consumers due to simple logistical barriers that more advanced value chains may avoid. Meanwhile, existing retail markets may be small, overcrowded, unsanitary and lacking cooling equipment, which can promote inefficiency and waste. Tighter system integration across the value chain may decrease food loss (Godfray et al., 2010; Parfitt et al., 2010; Gustavsson et al., 2011).

4.2 Food waste in developed countries

4.2.1 Retailer management and consumer behavior

Food waste during distribution and retail attracts much attention. It has been estimated that the food and retail industries are responsible for roughly one third of industry and commercial waste in the UK with volume figures between 18 and 22 mt per annum (Hogg, 2007; WRAP, 2008). There are several common reasons for food waste in these value chain segments, including safety and reputation concerns, forecasting failure, poor storage, inappropriate packaging, and poor handling and transportation (Kantor, 1997). According to a research in the UK, some food waste is inevitable, like damaged food during transport or unsold food due to sales lags. A great deal of food waste, however, is avoidable. Much of food waste is caused by failure of management and human error, such as inaccurate forecasting, over-ordering, packaging or labeling mistakes, breakages due to retailers' handling, and human error in inventory. Some waste results from the failure of equipment and insufficient shelf space. Demand changes from the unforeseen variation of weather can also contribute to food waste. Improved market information sharing, performance measurement, cold chain management, worker training, and waste management responsibilities could reduce waste

(Mena, 2011).

Food waste by consumers is more nuanced. Based on the food waste report from Worldwide Responsible Accredited Production (WRAP) 2008, households in the UK threw away 6.7 million tons of food (excluding drink), which means 270 kg per household per year or 5.3 kg per household per week, valued in $19.25 billion. A fifth, or about 4.1 million tons of waste, however, is avoidable if it were stored or managed better (WRAP, 2008). Usually households with more occupants will waste more total food but less per person than smaller households. Adults waste more food in absolute terms than children, and households with children waste more than households without children. No significant correlation between food waste and household income is found among Finnish households (Koivupuro et al., 2012).

Studies about home food waste are limited. Two possible reasons for home food waste include preparing too much food and not preparing food in time (WRAP, 2008; Parfitt et al., 2010). Too much food yield leftovers that can often go uneaten or can lead to food waste via over eating. Other reasons for not consuming purchased food includes confusions about sold-by, use-by and best-before dates on packages. Some consumers refuse to eat the food which is only several days before the best-before date or the sell-by date in fear of possible health risks.

4.2.2. Inexpensive food

According to standard economic models, people will determine food waste by equating the marginal benefit of wasting to its marginal cost. If people over-estimate low-probability risks of foodborne illness, perhaps in line with common probability weighting models, the expected marginal benefit may be higher than that derived by arms-length expert risk analyses. Moreover, without taking the externality of food waste into consideration, the marginal cost of food waste will be underpriced by households. With over-estimated benefit and under-estimated social costs, food waste will exceed socially optimal levels.

4.2.2.1 Food waste at the retailer level due to inexpensive food

In order to avoid costs from foodborne illness, food firms have incentives to waste food. If firms have product that may have an increased risk profile due to improper cooling, storage or handling, they may choose not to sell the food to the next link in the value chain to avoid risks to reputation, recall costs or legal risks (Daughety & Reinganum, 2011). For example, in the Sara Lee listeria outbreak case, the company recalled 15 million pounds of hot dogs and deli meat products, and recorded a pretax charge of $76 million for the recall, various fines and legal settlements (Roe, 2004). The expected losses for the expenditure above are parts of operating costs, and sometimes it can be much greater than the actual harms caused by problematic food. Executing a recall, for example, can induce large negative consequences for the firms. Not only are millions of dollars lost in the legal settlement, but many units of safe food which should have been part of firms' revenue and part of consumer meals will be wasted and thrown away or directly to lower value uses. Therefore, when estimating the expected loss from

the suspicious food, both the potential legal cost and the huge loss from the recalled safe food will be counted, and the total number might be much higher than the value of suspicious food itself. Furthermore, sometimes consumers may over-react or exaggerate the health related risk of suspicious food. Since retailers will either directly or indirectly compensate consumers for the food they 'feel' unsafe, retailers will also over-estimate the probability of the food being risky and exaggerate the damage that the seemly unsafe food could result in, as consumers do. To minimize the expected cost of suspicious food, whose harm and probability may be over-estimated, retailers may lean toward discarding problematic food and waste edible but seemingly unsafe food. By providing safer or at least seemingly safer food, a better reputation might be gained and a higher price could be charged for the increased quality and demand (Buzby & Frenzen, 1999). The expected loss avoided by wasting food and the expected gain from the seemingly better food is the benefit of the food waste for the firms.

Compared to the benefit of food waste, however, the cost of food waste is relatively low. Without taking the externality of food waste into account, the private cost of waste only contains the expected forgone revenue of the food and disposal fee. Moreover, during the food life cycle including producing, processing, transport and resale, some food is wasted inevitably. Given the benefit of wasting, the sum of food waste cost and the remaining expected legal expenditure will be lower than the social optimum with private costs below social costs. With this lower private cost, retailers are able to buy more food and result in extra food waste during the food's life cycle. The "inevitable waste" brought about by under-estimated cost should have been avoided if the cost of food waste valued its externality. Based on the over-estimated benefit and the under-valued cost, firms will waste more than the social optimal level.

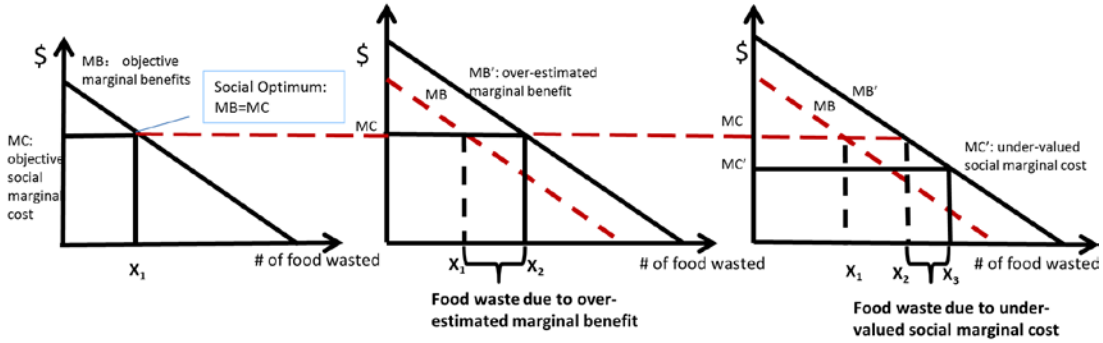

Figure 1.1. Food waste under objective social marginal costs and marginal benefits

Figure 1.2. Food waste when marginal benefits of waste are over-estimated

Figure 1.3. Food waste when marginal benefits are over-estimated and social costs don't internalize the externalities

4.2.2.2 Food waste at the consumer level due to inexpensive food

In some countries and eras, and for some consumers with higher incomes, food

available in private retail markets may be so inexpensive that they are able to afford waste and so are less careful about managing potential food waste. Such consumers may prefer to fully insulate themselves from the health risks of home prepared foods that have been mishandled or whose preparation has been delayed by employing the 'when in doubt, throw it out' heuristic. Given the low probability of successful legal cases in the event of foodborne illness, the benefits of food waste for consumers are the expected avoided damages, including avoided pain, suffering, time loss and all other health and financial costs. They might over-estimate the health risk due to the lack of accurate health information, misperception of what they may suffer from the potential foodborne illness, or the confusions about 'sell-by', 'use-by', and 'best-by' package dates. The cost of the waste, however, is likely under-valued by consumers on several fronts. In addition to the unaccounted externalities mentioned earlier, consumers may further under-estimate the cost of food waste because they may not remember the amount they spent on food items, or the people who prepare food and dictate waste are not the same people who purchased the food, so that the actual food wasters are unaware of the cost of wasting. With tendencies to over-estimate health risks and forget costs, we can expect consumers to waste much more food than is socially optimal.

4.2.3. Food waste due to over-nutrition

Relatively inexpensive food may also induce consumers to eat more than needed to maintain a healthy body weight. The actual daily food requirement ranges between 1,500-2,000 kcal/capita for adult females and 2,000-2,600 kcal/capita for adult males, with a weighted mean for entire population of around 2,000 kcal/capita. To provide an adequate safety margin and take inevitable food losses into consideration, 30% of food should be added to the mean, which means no more than around 2,600 kcal/capita is required to maintain body demand and food security. According to FAO's food balance sheet, however, all high-income countries have more than 3,000 kcal/capita per day available at retail level. The differences between the current calories supplied and required could supply another 350 million people in the high-income countries, or twice as many people with Asian diet which consists of primarily vegetarian calories. The supply and pricing of food in higher-income countries often result in high rates of obesity and commensurate health costs (Smil, 2004a). In 2001-2002, 65.7% of adults in the US were either overweight or obese (Hedley et al., 2004), and Healthy People 2010 identified over-weight and obesity as one of the ten leading health indicators (Healthy People, 2010).

Note that food energy content is less related to food cost than to the type of food chosen. Some healthy foods like fresh fruit and vegetables may have low energy (calorie) content but may have relatively higher cost for people to maintain body functions than energy intense food, because they may require more labor during the production and processing and more advanced transportation and preservation technology. A study in European finds that 15% of an EU sample mentioned price as a barrier to healthy eating (Pollard, Kirk & Cade, 2002; Lappalainen et al., 1997). Substantial

research has documented that food insecurity could be a significant predictor of obesity and overweight, even after controlling for socioeconomic, demographic, government assistance, environmental and lifestyle variables (Dinour, Bergen & Yeh, 2007; Townsend et al., 2001; Olson, 1999). People in food insecurity group may prefer cheaper energy-intense food to healthier but more expensive low energy food. As a result, for some foods wasted in the form of over-nutrition, the reason why energy intake increases is not because food is so cheap, but rather because food insecure individuals could eat more energy intensive food on a given budget.

4.2.4 Food waste due to large packages

Inappropriate package design could also result in food waste. The following are common reasons mentioned for food waste: "buying too much," "multi-packs," "buy one get one," "food gone past its sell-by date," and "package too large to empty." (Cox & Downing, 2007) 30% of consumers believe that large packages are one potential reason for food waste according to a Norwegian study. A survey in Swedish found that 20-25% of food waste in the households is related to packaging issues (Williams et al., 2012). Few households in this survey mentioned the impact of over-consumption due to large packages on "food item gone bad." If taking the unnoted over-consumption into account, the food waste attributable to packaging will be even greater. Nevertheless, concerns about the environmental impact of discarded packages could prevent the improvement of package design. In UK, almost three-quarters of people agree that 'discarded food packaging is a greater environmental issue than food thrown away.' (WRAP, 2007a). On the contrary, research has demonstrated that food with appropriate smaller package, which are easy to empty and reseal and provide correct information about content and best-before-use (Löfgren, Witell & Kano, 2005), will almost certainly have less environmental impacts than food sold in larger packages (Williams et al., 2012).

4.2.5. Food waste due to large portion size

Portion size could also exert powerful effects on the amount of people intake (Herman & Polivy, 2005). Studies have demonstrated that larger portion sizes are likely to induce people to intake more food and energy by providing visual illusions and biased perceptions of the amount of food they consumed (Van Ittersum & Wansink, 2011; Diliberti et al., 2004; Rolls, Roe & Meengs, 2007). According to a field experiment, buffets in hotel restaurants are able to reduce around 20% of food waste, simply by reducing plate size and providing social cues that encourage consumers to serve themselves more than once (Kallbekken & Sælen, 2013).

5. Rebound Effects

In this section we explore the potential that reductions in food waste may have general equilibrium effects that offset the initial food savings induced by food waste reduction initiatives. This 'rebound effect' has origins in the energy economics literature (van den Bergh, 2011) but is likely relevant for food waste scenarios too. A canonical example was the rapid depletion of England's coal reserves in response to an

exogenous improvement in coal-use efficiency (Jevons, 1865). In the food waste case, rebound effect exists as well.

Consider an exogenous technology advance which could decrease supply-side food waste. The first consequence of this efficiency improvement is that a portion of the saved food will be wasted by the consumer so that the food waste at consumer level will increase and the total food saved by the technological advance will be less than we expect. Furthermore, a drop in supply-side waste could decrease input use, which through decreased input prices, could yield more output via general equilibrium adjustments, which may result in even more food output. However, a part of the newly increased output will again give more waste on the demand side. Finally, in the market, the increased food supply will drive down the food price, meaning the marginal cost of food waste in the eyes of the consumer will decrease. Therefore, we could expect more food will be wasted due to the inexpensive food issue discussed earlier. The rebound effect of an exogenous technology reduction in supply side food waste consists of these and other possible general equilibrium adjustments that might offset the initial gain in food supply. Hence, policy interventions or technology advances aimed at reducing food waste may be overstated if the rebound effect is not considered (van den Bergh, 2011).

6. Waste Management

While it may be first best to prevent food waste in the supply chain and avoid both over-consumption and over-eating, the realistic issue remains concerning how to sustainably manage the food that is wasted. According to the food recovery hierarchy from Environmental Protection Agency (EPA), a series of management approaches from the most preferred to the least preferred, are to feed hungry people, feed animals, recover for industrial use, compost, and then landfill or incinerate. We can also simplify it as '3Rs', Re-use, Recycle, and Recovery (Mohanty, 2011), and disposal.

There are many ways to reuse surplus or imperfect food. For example, a French supermarket, Intermarché, sells ugly fruit and vegetables in a separate section with 30% discount, instead of discarding the items (Galliot, 2014). In Boston, people are planning to launch stores selling food just past the labeled date or food discarded by supermarket at very low price to feed people suffering from food insecurity (NPR, 2013). Nonprofit organizations, including food bank, food pantries, and neighborhood charity outlets, are established to collect food and offer it to hungry people. Farmers and retailers could donate unharvested, unsold, or other imperfect food to such organizations, and, at the same time, save a large number of waste-removal fees (Kantor et al., 1997). Volunteers in these organizations will review all the donated food and distribute it to food insecure people. In this way, food is re-used by needy people and donors could also benefit from a reduction in disposal costs.

For food that is not good enough for humans, it can be recycled into animal feed. If recycling food into animal feed is not feasible, it may be efficient to convert it into biofuel or to convert it into a nutrient-rich soil amendment via composting since at least

food decay in compost presented with oxygen will not produce methane, a potent greenhouse gas (Gardiner, 2014). Finally, after all the efforts above are exhausted, disposal in landfill will be the last and the least favorable choice.

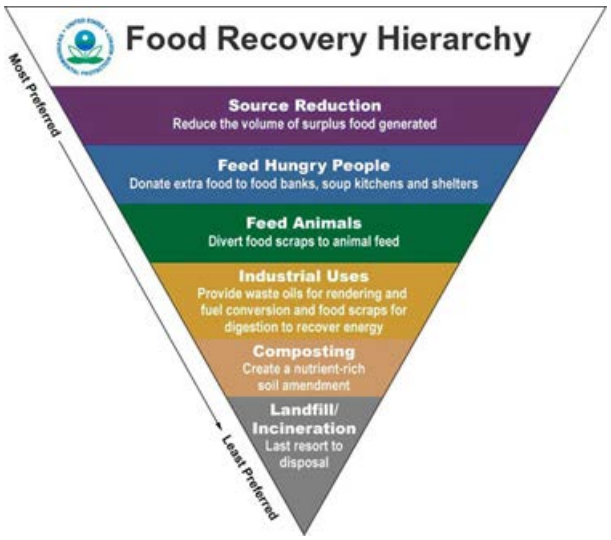

Figure 2. Food Recovery Hierarchy

7. Conclusion

In this review we summarize possible causes of food waste, potential methods to reduce the waste and methods to manage the wasted food sustainably. In developing countries, considerable food can be saved by improvement of infrastructure, integration of markets, and improved rural credit. In developed countries, food waste is related to firms and consumer behaviors that may be based on private costs that do not include social costs such as the externalities associated with food waste and the over-estimation of the benefits of food wasted associated with the avoidance of damages from foodborne illness. Information programs clarifying food related health risks and the interpretation of best-by, use-by, and sell-by label dates may help consumers recognize food that can be harmful to them and estimate the harm of marginal food more rationally. Programs informing consumers about the environmental externality of food waste may help people to better understand the cost of food waste. With greater and more reliable information, consumers and so that firms could make better decisions and at least reduce food waste induced by asymmetric information (Gilligham, Newell & Palmer, 2009). To internalize the externalities of food waste, Pigouvian taxes on food waste such as those recently implemented in Korea might be considered for broader implementation. Taxes on food could also curb waste by incentivizing consumers to waste less food, but such policies

can also exacerbate the food insecurity situation of lower income individuals. Nevertheless, estimation of the social benefits and social costs including the externality of food waste are required to set appropriate policy interventions and, to our knowledge, this information has not been robustly estimated. Further research concerning these issues is essential to analyzing food waste behavior, reducing waste, and increase economic efficiency and sustainability

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