On the Measurement of Food Waste

presented by

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Introduction

If one is to believe some of the popular rhetoric surrounding it, food waste is a—if not *the*—defining food policy issue of our time.

As with many other food policy issues ranging from famine to GM foods and from undernutrition to obesity, food waste elicits an almost visceral reaction.

This likely due to the social norms and value judgments associated worldwide with the wasting of food.

Introduction

Sound measurement of food waste is central to sound policy making

However, the estimates of the quantity and cost of food waste provided by major institutions are vastly different

According to FAO one-quarter to one-third of all food produced worldwide is wasted

Food waste estimates in the US range from 35 million tons to 103 million tons

The extant definitions of food waste provided by FAO, ERS, FUSIONS, and EPA are not consistent with one another

Thus, we do not have an unambiguous way of measuring food waste as well as costs associated with food waste.

Introduction

We develop a simple framework to systematically think about food waste based on the life cycle of a typical food item.

Based on this framework, we:

- identify shortcomings with extant measures of food waste and propose a more consistent and practical approach
- Provide a systematic way to think about the cost of food waste which, much like the use of value added in calculating GDP, solves the problem of overvaluation due to double counting.
- Document the points in the life cycle of a typical food item where policy makers can intervene and identify interdepecincies between these points.

The Life Cycle of Food

The life cycle of a typical food item is comprised of four generic, stylized phases : (i) growers (g), (ii) processors (p), (iii) retailers (r), and (iv) consumers (c).

As food moves down the supply chain, food loss occurs at any stage when food is taken out of the supply chain. Lost food either goes to the landfill, or it is put back into the food supply chain or goes to nonfood albeit productive uses.

The Life Cycle of Food

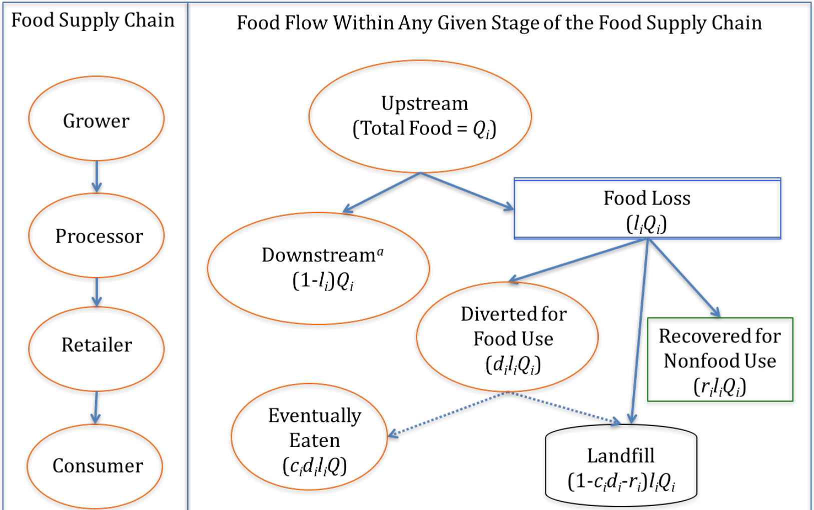
Let's take stage g as an example. Total food available Q_g either flows to the downstream sectors ($[1 - \ell_g]Q_g$) or leaves the food flow ($\ell_g Q_g$) at a fraction $\ell_g \in [0, 1]$.

A fraction of food lost $d_g \ell_g Q_g$ is diverted back to the supply chain (e.g., gleaning, market for ugly produce), where $d_g \in [0, 1]$. Another fraction of food lost $r_g \ell_g Q_g$ is recovered for nonfood use (e.g., feed, fuel, fertilizer).

The Life Cycle of Food

A fraction $c_g d_g \ell_g Q_g$ of food diverted back is eventually consumed.

The remainder goes to the landfill $(1 - c_g) d_g \ell_g Q_g$ due to food waste stemming from handling, cooking, and neglect by consumers.



a. Downstream flow does not occur at the consumer stage.
Key: *i* indexes stages of the food supply chain. Oval – food flow within the supply chain, blue arrow – direct food flow, dashed-blue arrow – direct or indirect food flow.

The Life Cycle of Food

All the parameters of the food flow in Figure 1 appear in the phases of food loss, determining the proportion of food that flows outside of its supply chain.

These parameters are intervention points, or policy levers. For example, if $\ell_c > \ell_g > \ell_p > \ell_r > 0$, policies can be directed to reduce the burden of food loss at the consumer, grower, processor, and retail levels, in order of importance.

The Life Cycle of Food

The foregoing applies to food systems in both developed and developing countries. Differences across various types of foods, industries, and countries are differences in parameters at each stage.

For instance, the ℓ parameters depend largely on infrastructure and technology. More advanced and efficient food industries in developed countries imply smaller loss parameters at the farm and intermediary levels than nascent value chains in developing countries.

Definition and Measurement

The FAO (2016) defines food waste as follows:

> *Food loss is defined as "the decrease in quantity or quality of food." Food waste is part of food loss and refers to discarding or alternative (nonfood) use of food that is safe and nutritious for human consumption along the entire food supply chain, from primary production to end household consumer level.*

Definition and Measurement

Similarly, when discussing food loss versus food waste, the USDA's ERS (Buzby et al. 2014, p. 1) defines food loss and food waste as follows:

> *Food loss [is] the amount of food postharvest ... available for human consumption but ... not consumed ... It includes cooking loss and natural shrinkage ...; loss from mold, pests, or inadequate climate control; and food waste.*
>
> *Food waste is a component of food loss and occurs when an edible item goes unconsumed, as in food discarded by retailers due to color or appearance, and plate waste by consumers.*

Definition and Measurement

The EU's FUSIONS task force defines food waste as follows:

> *Food waste is any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composed [sic], crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea).*

Definition and Measurement

Finally, the US EPA's food waste estimate is described as follows (EPA, 2016):

> *[T]he amount of food going to landfills from residences, commercial establishments (e.g., grocery stores and restaurants), institutional sources (e.g., school cafeterias), and industrial sources (e.g., factory lunchrooms). Pre-consumer food generated during the manufacturing and packaging of food products is not included in EPA's food waste estimates.*

Definition and Measurement

Those definitions are all lacking in some way. Based on Figure 1, according to FAO, ERS, and FUSIONS, food waste is the sum of the "landfill" and the "recovered for nonfood use" parts.

Counting food recovered for nonfood use as food waste is an important shortcoming of these definitions: If recovered food is used as an input, it is not wasted.

Definition and Measurement

Unlike the other definitions, the EPA's definition food waste does not count food that is recovered for productive nonfood use as food waste.

But the EPA's measurement only includes food that ends up in a landfill from the retail and household stages of the food supply chain—any waste resulting from the grower and processor stages is not counted in the EPA's measure.

Definition and Measurement

Another inconsistency between these definitions is that the FAO and ERS definitions only apply to edible and safe and nutritious food, whereas the FUSIONS and EPA definitions apply to both edible and inedible parts of food.

Finally, the ERS and EPA definitions exclude food that is not harvested at the farm level.

Definition and Measurement

We propose a definition of food waste that overcomes all these shortcomings and which leads to an unambiguous way of measuring food waste and its costs.

Our definition considers productive uses of food, whether "productive use" means consumption, fertilizer, feed, or fuel. If it does not end up in a landfill, it is not wasted.

Lastly, our definition of food waste includes food that is wasted at all stages of the supply chain. This is important to properly assess the value or cost of food waste.

Definition and Measurement

Definition (Food Waste)

Let $\overline{y}$ denote the quantity of food produced. Let $i \in \{1, ..., N\}$ denote the N potential productive uses for food. For each productive use, a certain amount of food $y_i < \overline{y}$ is employed. Food waste is any quantity $w > 0$ such that $w = \overline{y} - \sum_{i=1}^{N} y_i$.

The Value of Food Waste

I will not be discussing this here, but in the paper, we also show how extant estimates of the value of food waste are overstated.

This is both because the quantity of food waste is overstated, but also because the price used to value wasted food is very often the retail price, when in fact waste often occurs before the retail stage, at lower prices due to less value added at earlier stages of the supply chain.

The Value of Food Waste

The foregoing is limited to the monetary value of waste, which one can think of as accounting costs in the theory of the firm.

But the total cost of food waste also includes the costs—monetary or otherwise—associated with the social and environmental costs of food waste, which one can think of as economic costs.

One shortcoming of our cost estimate is that it ignores externalities. Another shortcoming is that it ignores the landfill-related costs of food waste.

Other Measurement Issues and Policy Implications

We now turn our attention to the parameters that link various Q variables in the stylized food system laid out earlier—those are points of policy intervention.

Accordingly, various policies can be implemented to reduce loss (in the form of prevention) or to promote the diversion of food for both food and nonfood uses. We can monitor the effectiveness of the policies through changes in those parameters, which are important to estimate and subsequently track over time.

Other Measurement Issues and Policy Implications

The amount diverted for food and nonfood uses depends not only on the rate of diversion d_i but also on the loss rate ℓ_i, where $i \in \{g, p, r, c\}$.

Policy interventions are not independent, and a lack of explicit accounting of confounding effects can lead to a misallocation of food waste reduction efforts.

Other Measurement Issues and Policy Implications

Specifically, at each stage, the quantity of food waste w_i, where $i \in \{g, p, r, c\}$, is such that

$$w_i = (1 - d_i - r_i)\ell_i Q_i + (1 - c_i)d_i\ell_i Q_i,$$

or

$$w_i = (1 - c_i d_i - r_i)\ell_i Q_i.$$

which means that the total quantity $\mathcal{W}$ of food waste is such that $\mathcal{W} = \sum_i w_i$.

Other Measurement Issues and Policy Implications

The total quantity of food waste is decreasing in the proportion of food diverted d_i, the proportion of food recovered r_i, and the proportion of diverted food that is eventually consumed c_i at every stage.

Similarly, the total quantity of food waste is increasing in the proportion of food lost ℓ_i and in the quantity of food Q_i at each stage.

Other Measurement Issues and Policy Implications

Formally, at each stage $i \in \{g, p, r, c\}$ of the life cycle of food

1. $\frac{\partial \mathcal{W}}{\partial \ell_i} = (1 - c_i d_i - r_i) Q_i > 0$,
2. $\frac{\partial \mathcal{W}}{\partial Q_i} = (1 - c_i d_i - r_i) \ell_i > 0$,
3. $\frac{\partial \mathcal{W}}{\partial r_i} = -\ell_i Q_i < 0$,
4. $\frac{\partial \mathcal{W}}{\partial c_i} = -d_i \ell_i Q_i < 0$, and
5. $\frac{\partial \mathcal{W}}{\partial d_i} = -c_i \ell_i Q_i < 0$.

Other Measurement Issues and Policy Implications

This suggests specific policy interventions, many of which remain to be tested.

Moreover, policy priorities can be defined by estimated costs attached to the food waste generated at various stages of the chain.

The price of food increases as food makes its way downstream, so reductions in downstream food waste reduce the value of food waste more than reductions in upstream food waste, *ceteris paribus*.

Other Measurement Issues and Policy Implications

The interdependence between policy levers requires cooperation and coordination of all stakeholders in the food system. Otherwise, resources might be misallocated.

For example, investments in technology to promote diversion of food loss to nonfood use might be moot if policy makers could reduce food loss more easily.

Our framework helps identify strategic policy complementarities and substitutabilities when it comes to reducing food waste.