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The Economic Impacts of (Reducing) Food Waste and Losses: A Graphical Exposition

Martine Rutten

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Wageningen School of Social Sciences

Hollandseweg 1, 6706 KN Wageningen,
The Netherlands
Phone: +31 317 48 41 26
Fax: +31 317 48 47 63
Internet: http://www.wass.wur.nl
e-mail: wass@wur.nl

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Martine Rutten LEI-Wageningen UR, martine.rutten@wur.nl

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THE ECONOMIC IMPACTS OF (REDUCING) FOOD WASTE AND LOSSES: A GRAPHICAL EXPOSITION

Author: Martine Rutten, LEI-Wageningen UR

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Abstract

From a diagrammatic analysis of the economic theory of supply and demand, it can be shown that reductions in food losses and/or waste may improve food security of the wider population due to lower food prices and increased food consumption, if not in the market where losses and/or waste are reduced then elsewhere due to increased spending from savings on previously wasted food. Consumers, and producers in other commodity markets, will favour actions to combat food losses and/or waste of a particular food commodity, whereas its producers may object, especially when reducing food waste is concerned as this diminishes their revenues. Trade-offs also arise over time, as in the short-run producers may have to incur costs and welfare losses when food losses and/or waste are tackled, whereas the gains, if any, in terms of increased sales may only be realised later. Consumers may delay spending savings on previously wasted foods. How these trade-offs compare to the broader trade-offs between economic, health and environmental goals, also across countries, is an issue for policy makers. The outcomes of this and further formal and applied analysis are crucially depending on, amongst others, the extent to which losses and/or waste are avoidable, the costs involved, the causes of food losses and waste, including scale and price factors, and consumer preferences.

Introduction

Food waste is a contentious issue at times where hunger amongst the poor is still prevalent, but also the vulnerable increasingly have to fear for food insecurity due to frequent food price peaks (e.g. in 2007-08 and 2011-12) and adverse economic tidings. Given a growing population, pressures from competing claims of feed, food and fuel demands on scarce natural resources of water and land, are only likely to increase.

The numbers suggest that globally, compared to 2009, 70 per cent more food would have to be produced to satisfy the needs of a population growing by a third in 2050 (FAO, 2009). Evidence also suggests that close to one third of the edible parts of food produced for human consumption, gets lost or wasted globally, equivalent to around 1.3 billion tonnes per year (FAO, 2011). In low-income countries, these so-called 'losses' in edible food mass destined for human consumption mostly occur in production, postharvest and processing stages. In medium- and high-income countries these losses occur mostly at the end of the food chain (retail and final consumption), and are termed 'waste' (Parfitt, Barthel and MacNaughton, 2011).[1]

[1] The reference definition that is being developed by the FAO as part of the Save Food initiative also includes qualitative losses such as losses in nutritional value. The definition of food losses and food waste is subject to debate. The distinction between food loss and food waste is, for example, unclear. The definition of what is edible also varies across time and countries. Finally, it depends on the perspective taken. For example, from a

Combining these two observations may suggest that reducing food losses and/or waste could relieve part of the pressures and enhance food security[2] of especially the poor and vulnerable. Specifically, it would, first, reduce production costs and increase sales for producers and, second, increase food available for consumption at lower prices for households.[3]

These impacts have, so far, not been investigated empirically due to lack of reliable and consistent data.[4] Lower prices, while beneficial to net food consumers, are harmful to net food producers. Producers may actually lose out from reductions in waste in consumption as sales and prices, and so incomes, are likely to be negatively affected. It is also doubtful whether reducing food losses and notably waste in medium- and high-income countries would help the poor and vulnerable in low-income countries, where food insecurity is an issue. Food availability on the world market may increase which lowers world prices and could benefit net food consumers (or importers) but harm net food producers (or exporters) in the developing world. This depends however on the trade/local content of foods consumed in developing countries and whether or not tariff or non-tariff barriers to trade exists which may prevent the free movement of food commodities altogether. It is questionable whether the avoided waste in medium- and high-income countries will end up with consumers in developing countries. Generally, costs may be involved in reducing food losses and/or waste, undoing the potentially beneficial impacts of reducing it and which may motivate the existence of food losses and/or waste in the first place.[5] Finally, lower food prices could encourage waste as it is cheap[6] and/or enhance resource inefficient (e.g. meat) consumption via lower (feed) prices. It could also encourage the use of biofuels.[7] Such issues are best investigated empirically, using an applied model, which can distinguish different types of food commodities and their interrelations in the food supply chain from farm to fork and within the broader (global) economy, i.e. a Computable General Equilibrium type of simulation analysis.[8]

It is useful to start an analysis of the economic impacts of (reducing) food waste and food losses with a theoretical framework, which guides the interpretation of the outcomes of a more complex empirical model with added real-life complexities. This paper aims to provide

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food security perspective, biofuels, feed or other non-food secondary uses of what was intended for human consumption may be considered a loss, whereas from the perspective of generation of value-added, they are not necessarily. Alternatively, from a health perspective, food intake may be more appropriate than food consumption and anything in excess of reference levels may be interpreted as waste.

[2] Food security is most commonly 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).

[3] See for example FAO (2011; p1) and Lundvquist et al. (2008; p26) for this line of reasoning.

[4] The exception is a study by Westhoek et al. (2011) on meat consumption, also briefly looking at the issue of food waste. It finds that a reduction of food waste of 15% reduces agricultural prices by about 4% which increases food consumption. There is quite some literature that derives impacts of food losses and/or waste by assigning a value to the resources embodied in, or the output that could have been realised by avoiding, the losses and/or waste (for an overview see BCFN, 2012). This only says something about the scale of the problem, not the impacts, as it ignores interactions between demand and supply, the role of the price mechanism therein, and more generally interactions between actors and sectors in the food system and the wider economy.

[5] Whereas some measures to reduce food losses and/or waste may be costless (e.g. behavioural change on the part of consumers or producers), others may involve quite significant costs (e.g. investments in storage facilities). Consistent global data on costs are hard to find.

[6] See, for example, BCFN (2012; p34 and 54).

[7] This is found by the study of Westhoek et al. (2011). The literature (e.g. FAO, 2011; p2) would label food use by biofuels or other non-food secondary uses as a loss, if it was originally edible and intended for final consumption by households. This is subject to debate as one can also argue that this alternative use generates an economic value and thus is not lost.

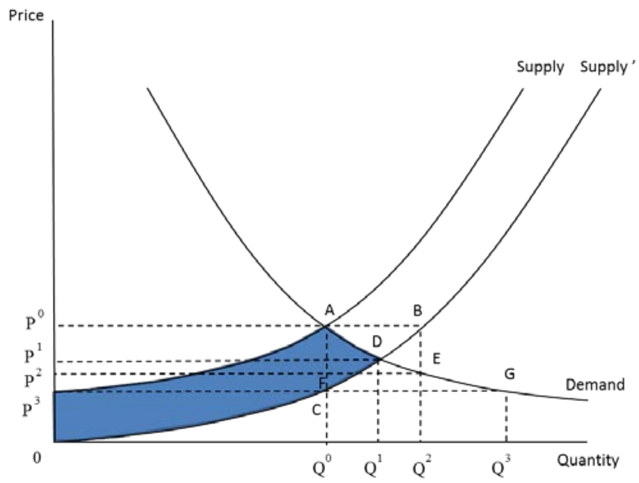
[8] Two CGE applications focussing on, respectively, reducing food losses in supply and reducing food waste in demand are forthcoming in two different papers.

such a theoretical framework, which, to our knowledge, is missing from the literature so far. The paper provides a simple diagrammatic analysis of expected impacts using standard economic theory of supply and demand.[9] Section 1 elaborates on the economic impacts of reducing food losses in supply. Section 2 elaborates on the economic impacts of reducing food waste in demand. Section 3 provides a synthesis. The final section concludes.

1. Reducing food losses in supply

In this section we examine the economic impacts of (reducing) food losses in a low-dimension partial equilibrium analysis. Figure 1 depicts the market for a food commodity[10], with a standard upward sloping supply curve and a standard downward sloping demand curve. The price mechanism ensures that demand equals supply. The equilibrium is reached at point A, where the price is P^0 and the quantity traded is Q^0.

Figure 1: Impacts of reducing food losses in supply



Let us assume that there are losses in the production and supply of this food commodity. In such a situation, the socially optimal supply curve, or the supply curve of this food commodity that would not have these losses, lies below the original supply curve, as depicted by $Supply'$ in Figure 1; given the original price, P^0, more can actually be produced and supplied to the market (Q^2 at point B), or the original quantity, Q^0, can actually be produced at a much lower cost (P^3 at point C) if losses were to be absent.[11]

Avoiding these losses, given the original demand curve, would thus result in a lower price, P^1, and a higher equilibrium quantity, Q^1, in the market, as given by point D. At this new equilibrium consumers can buy more food at a lower price, resulting in a welfare gain to consumers as measured by the change in the consumers surplus of P^0ADP^1. Similarly, producers can sell more, but at a lower price, resulting in a change in the producer surplus of $P^1D0 - P^0AP^3$, which is also positive. The overall welfare gain equals the sum of the change

[9] A more formal analysis using mathematical equations could also have been chosen, but such an approach is less intuitive compared to the use of diagrams. A different forthcoming paper develops the formal theory behind the diagrammatic analysis in more detail.

[10] While this paper considers the economic impacts of food losses, the issue of losses, or more broadly, resource inefficiencies, is not only confined to food but is also applicable elsewhere. This analysis can therefore be extended to other non-food commodities.

[11] Note that the 'optimal' supply curve does not necessarily have to be parallel to the original supply curve, as the extent of losses may vary with the scale of production (and price). We abstract from this for ease of exposition.

in the producer and the consumer surplus, which amounts to the area P^3AD0, the blue shaded area between the new and old supply curve and under the demand curve.

The outcome and so the size of the welfare effects depends on the slope of the demand and supply curves. Assuming that the extent of losses is the same as before (i.e. the shift in the supply curve is of the same distance as before), and independent of scale and/or price, we can distinguish the following cases (see Appendix A1). In the presence of a perfectly inelastic (i.e. vertical) demand curve, the new equilibrium is at point C, with consumers receiving all the gains from reducing food losses in the form of a lower price and a welfare gain of P^0ACP^3.[12] In the presence of a perfectly elastic (i.e. horizontal) demand curve, avoiding food losses in supply results in a new equilibrium at point B, where all the gains translate into an increase in the equilibrium quantity supplied and demanded. This results in a welfare gain to producers of P^3AB0. Similarly, if supply is perfectly inelastic (vertical supply curve), the equilibrium is at point E, resulting in a lower equilibrium price and higher equilibrium quantity compared to the analysis before. Consumers gain by P^0AEP^2, but producers here lose out by $FEQ^2Q^0 - P^0AFP^2$. The overall welfare result, however, is positive (area AEQ^2Q^0). Finally, a completely elastic (horizontal) supply curve results in an equilibrium at point G, whereby demand increases the most (to Q^3) as the price falls the most (to P^3) and all welfare gains end up with the consumers who benefit to the maximum extent possible, by area P^0AGP^3.

In this simple, low-dimension diagrammatic analysis, overall welfare, and specifically the welfare of consumers, generally goes up, whereas that of producers could go down, namely in the case of supply being relatively inelastic. This is an interesting finding as it suggests that producers of food commodities such as crops, which in the short-run have a relatively inelastic supply curve given the time it takes before they are ready to be harvested, may be worse off in the short-run when tackling food losses. In the long-run, supply of agricultural commodities is almost perfectly elastic, so then welfare gains are likely to occur (and most, if not all, of these end up with the consumer).[13]

We have, however, made various simplifying assumptions to come to our findings. Firstly, we assume throughout the analysis that all losses in the production and supply of this food commodity are avoidable, that they are independent of scale (and price) and that they are costless to diminish. In reality this may well be different so that the outcomes may differ. Specifically, the impacts may be much smaller if only a part of the food losses is avoidable, and the net welfare gains will be lower if there are costs involved. These costs will have a price increasing and quantity reducing effect in the market for the food commodity in question, undoing the original shift down (or to the right) that occurs when reducing food losses in supply. Moreover, if losses increase with scale (and price), the observed impacts of reducing food losses will be greater if the market is of a reasonable size (i.e. the quantity demanded and supplied is large) and the price is high; and vice versa, if losses decrease with scale (and price), impacts of reducing losses will be bigger if the market is small and the price is low.[14]

Another simplification is that we ignore where the losses occur in the supply chain (intermediate inputs, factor inputs), and that we abstract from interactions with other markets and actors. Our analysis makes the usual *ceteris paribus* assumption, i.e. that all else remains

[12] For most staple foods, demand will be fairly inelastic. For other foods, e.g. more luxurious types of food such as fish and red meat, this is not the case and elasticities will be much higher.

[13] This finding suggests the importance of inter-temporal effects, not addressed in this simple low-dimension partial equilibrium framework.

[14] Note that in the former (latter) situation, the supply curve with and without losses would increasingly diverge from one another as the quantity and price increases (decreases).

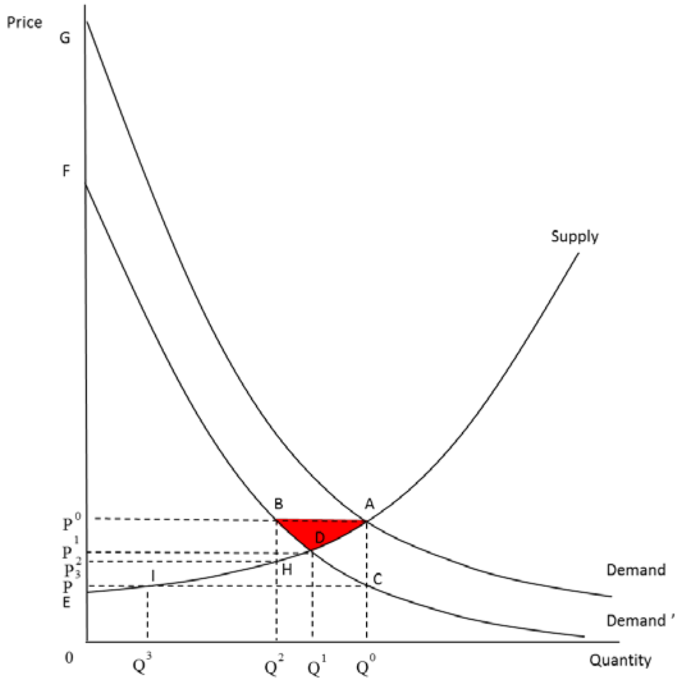
the same, which is highly unlikely. For example, reducing losses generally results in a lower price, which could increase demand elsewhere in the system, potentially leading to second-order effects. An example is wheat becoming cheaper if losses in production and supply fall, as a result of which meat demand may go up (as meat will become cheaper to produce due to lower intermediate input costs of using wheat). Similarly biofuel use may go up. Another example is that households may waste more if food becomes cheaper, undoing the positive impact of reducing food losses on the supply side.[15]

What exactly will happen remains an empirical question and is best investigated in an applied model of the whole economy with added real-life complexities. Nevertheless, these effects will still operate in the background and thus give a useful guide to the interpretation of the outcomes of such a model.

2. Reducing food waste in demand

In this section we examine the economic impacts of (reducing) food waste in a low-dimension partial equilibrium analysis. Figure 2 depicts the market for a food commodity, again with a standard upward sloping supply curve and a standard downward sloping demand curve and the equilibrium at point A, where the price is P^0 and the quantity traded is Q^0.

Figure 2: Impacts of reducing food waste in demand



Let us assume that there are losses in the consumption of this food commodity, in that consumers waste part of what they demand. In such a situation, the socially optimal demand curve, or the demand curve that would not have these losses, lies to the left of the original demand curve, as depicted by $Demand\ '$ in Figure 2; given the original price, P^0, less needs to be consumed (Q^2 at point B) so as to reach a certain level of utility if waste was to be

[15] Of course, consumers under pressure from prevailing morale may also display the opposite behaviour and reduce food waste. This is the topic of the next section.

absent, or the original quantity, Q^0, represents a much lower value to the consumer (P^3 at point C).[16]

Avoiding waste in consumption, given the original supply curve, would thus result in a lower price, P^1, and a lower equilibrium quantity, Q^1, in the market, as given by point D. Since producers are able to sell less and at a lower price, their welfare is negatively affected as shown by a change in the producer surplus of $P^1DE - P^0AE = -P^1DAP^0$. Taking the difference between the area under the new and old demand curve and above the new and old price respectively, $P^1DF - P^0AG$, would result in a change in the consumer surplus of $P^1DBP^0 - BAGF$, the sign of which is ambiguous depending on the size of the shock on demand and price.[17] This would ignore, however, the fact the old demand curve encompasses waste, so that consumers only realise P^0BF in value when consuming Q^0 of the food commodity at a price P^0; the remainder, $BAGF$, is lost due to wastage. The change in the consumer surplus if waste is avoided thus amounts to $P^1DF - P^0BF = P^1DBP^0$, which is now positive. The overall change in welfare that results equals $P^1DBP^0 - P^1DAP^0 = -BDA$, the red shaded area in Figure 2, which is negative.[18]

To conclude that the overall welfare impacts of reducing wastage in demand would be negative is wrong since the analysis is still not complete. The question that remains is what consumers would do with the saved expenses on this particular food commodity, $P^0Q^0 - P^1Q^1$. Consumers may want to add this amount to savings, in which case it could be used for consumption in future with associated utility gains or investments with a rate of return. Or, consumers may want to spend it now on the consumption of other commodities, and perhaps food. In this case it would lead to a shift in the demand curve(s) of the respective commodity(ies) in the opposite direction of that depicted in Figure 2, i.e. a shift to the right, leading to a higher price and quantity in the accompanying market(s) and a welfare gain in this (these) market(s) for producers in terms of an increase in the producer surplus, and a potential welfare gain for consumers if the change in the consumer surplus is positive. The overall welfare change(s) in this (these) respective market(s) would be positive and equivalent to the difference between the new and old demand curves and above the supply curve (if one were to take the example of Figure 2, $DAGF$).

The overall welfare impacts in the market of the food commodity in which waste is reduced and other markets combined depends on consumer preferences. Nonetheless, the welfare loss for producers, that occurs due to waste reduction by consumers of the food commodity in question and arises due to a fall in the price of the food commodity in question, is highly likely to be counteracted by welfare gains for producers and consumers in other markets.[19]

[16] Equivalent to the analysis on the supply side, the 'optimal' demand curve does not need to lie parallel to the original demand curve as the extent of waste in demand may vary with scale and price. We abstract from this for ease of exposition.

[17] In Figure 2 the effect seems to be negative.

[18] Note that if one, mistakenly, were to include the area $BAGF$, the overall welfare loss would amount to $DAGF$, the difference between the two demand curves and above the supply curve, which is analogous to the result of the analysis of loss reductions on the supply side. The analysis on the demand side differs from that on the supply side in that the original demand curve includes wastage, i.e. represents gross demand, whereas the original supply curve is the supply that would result after losses, i.e. it represents net supply.

[19] This is the second notable difference with the analysis of loss reductions on the supply side. Specifically, the loss reduction on the supply side is assumed to benefit the commodity in question in terms of lower costs of producing the same amount of good and/or increased outputs given costs. On the demand side however, it is almost more relevant to know what happens in other markets depending on consumer preferences and following consumer decisions on what to do with the saved expenses on the commodity that previously had wastage.

As before, the outcome and so the size of the welfare effects depends on the slope of the demand and supply curves. Ignoring what happens in other markets and focusing on the market of the food commodity in which waste in demand is reduced (see Figure 2), we can distinguish the following cases (see Appendix A2).[20] In the presence of a perfectly inelastic (i.e. vertical) demand curve, the new equilibrium is at point H, resulting in a lower equilibrium quantity, Q^2, and a lower price, P^2. The change in the consumer surplus would again be positive and equal to the area, P^2HBP^0, whereas the change in the producer surplus would be negative and equal to $-P^2HAP^0$. The resulting overall welfare loss in this market is $-HAB$, slightly more negative than before. In the presence of a perfectly elastic (i.e. horizontal) demand curve, avoiding food waste in demand results in a new equilibrium at point I, with an even lower quantity, Q^3, and price, P^3. This would result in a higher welfare loss in this market for producers, equal to $-P^3IAP^0$, but no impact on consumers. Similarly, if supply is perfectly inelastic (vertical supply curve), the equilibrium is at point C, where the reduction in wastage in demand fully translates into a lower equilibrium price, P^3, but has no impact on quantity. This lower equilibrium price benefits consumers, by P^3CBP^0, but hurts producers, who suffer a maximum loss of $-P^3CAP^0$, resulting in an overall welfare loss in this market of $-CAB$. Finally, a completely elastic (horizontal) supply curve results in an equilibrium at point B, whereby there is only a negative impact on the equilibrium quantity, to Q^2, but no impact on price, which would result in zero impact on producers and consumers in this market.

In this simple, low-dimension diagrammatic analysis of reducing waste in demand, consumer welfare generally goes up or at best remains the same, whereas producer welfare falls or at best remains the same, resulting in an overall welfare impact ranging from negative to, at best, zero in the long-term when the supply of agri-food commodities is almost perfectly elastic. As indicated before, the analysis above excludes interactions with other markets. Welfare gains to producers and consumers in other markets will result if consumers decide to spend the saved expenditures on other commodities.

We have also made various other simplifying assumptions to come to our findings. Firstly, we assume throughout the analysis that all waste in the consumption of this food commodity is avoidable, that it is independent of scale (and price) and that it is costless to diminish. In reality this may not be the case and, hence, the outcomes may differ. Specifically, the impacts may be much smaller if only a part of the food waste is avoidable, and the net welfare gains will be lower if there are costs involved to the consumer. These costs will have a price increasing and quantity reducing effect in the market for the food commodity in question, undoing the original shift down (or to the left) that occurs when reducing food waste in demand. Moreover, if waste increases with the amount consumed and decrease with price, the observed impacts of reducing food waste will be greater if the market is of reasonable size (i.e. the quantity traded is high and the price is low) and vice versa if waste decreases with scale of demand and increases with price, impacts of reducing losses will be greater if the market is small.[21]

Our analysis generally makes the usual *ceteris paribus* assumption, i.e. that all else remains the same, which is highly unlikely. Again, what exactly will happen remains an empirical question and is best investigated in an applied model.

[20] Throughout the analysis we assume that the extent of waste is the same as before (i.e. the shift in the demand curve is of the same distance as before), and independent of scale and/or price.
[21] Note that in the former (latter) situation, the demand curves with and without waste would increasingly diverge from one another as the quantity increases (decreases) and the price decreases (increases).

Table 1 Synthesis of impacts of reducing losses and waste in the market for a food commodity

	Impact on market equilibrium		Welfare impacts in the commodity market			Other factors and impacts
Reducing losses in supply	**Price**	**Quantity**	**Consumers**	**Producers**	**Total**	• If losses increase (decrease) with scale and price, then impacts are larger at higher (lower) scale and price • Impacts may be smaller if not all losses are avoidable • If loss reductions involve costs then welfare impacts will be lower. This has a price increasing and quantity reducing effect. • Interactions with other actors and/or markets
Perfectly inelastic demand curve	-	Constant	+	Constant	+	
Perfectly elastic demand curve	Constant	+	Constant	+	+	
Perfectly inelastic supply curve	-	+	+	? (-in example)	+	
Perfectly elastic supply curve	-	+	+	Constant	+	
Reducing waste in demand						• If waste increases (decreases) with scale and decrease (increase) with price, then impacts are larger at higher (lower) scale and lower (higher) price • Impacts may be smaller if not all waste is avoidable • If waste reductions involve costs then welfare impacts will be lower. This has a price increasing and quantity reducing effect. • If consumers spend savings from reducing waste: positive impact on price, quantity and welfare of producers and consumers in other commodity markets • Interactions with other actors and/or markets
Perfectly inelastic demand curve	-	-	+	-	-	
Perfectly elastic demand curve	-	-	Constant	-	-	
Perfectly inelastic supply curve	-	Constant	+	-	-	
Perfectly elastic supply curve	Constant	-	Constant	Constant	Constant	

Notes: '+' means a positive impact, '-' a negative impact, 'Constant' implies that there has been no impact. Whereas the direction of effects is shown, their magnitudes are not as they depend on the underlying shocks and how they impact upon each of the variables.

3. Reducing food losses and waste: a synthesis and discussion

Table 1 integrally presents the results of the supply and the demand side analysis. It summarises what happens to the market equilibrium (price, quantity; second and third column) and consumer and producer welfare (fourth and fifth column, and sixth column for the overall effect) in the market for the food commodity in question and for varying assumptions regarding demand and supply curves, providing the boundaries for what may happen (by row). The last column considers the impact of other factors where possible, i.e. relaxing some of the simplifying assumptions made throughout the analysis.

Table 1 shows that the analysis becomes much more complicated if waste in demand and supply would change simultaneously (and possibly in reaction to one another). Whereas the precise impacts taking into account real-life complexities are unknown and best analysed with an applied economic (CGE) model, some patterns can be observed from the results already.

3.1 Prices fall, but the traded quantity could rise or fall

The first pattern that emerges is that following reductions in food waste and/or losses, the price of the food commodity in question generally falls, whereas the traded quantity in the market could rise or fall depending on whether, respectively, the food loss or food waste reductions dominate. This conclusion continues to hold in the long-term, assuming a perfectly elastic (horizontal) supply curve (row six and eleven of Table 1).

3.2 Consumers are generally better off, producers may be worse off

Whereas consumers are generally better off when food losses and/or food waste are reduced, producers of the food commodity in question could be worse off, and again this is more likely if reductions in food waste dominate. The latter is simply not in the interest of producers who aim to maximise profits, even if it is on commodities that are wasted. In the long-term, assuming a perfectly elastic supply curve (row six and eleven of Table 1), the welfare losses for producers dissipate, though never turn into gains. These welfare losses, if any, will however be compensated for by welfare gains for producers and consumers in other commodity markets that are likely to benefit from increased spending of consumers using their savings on expenditures on the previously wasted food.

3.3 Costs undo the beneficial impacts of food loss and/or waste reductions

Both patterns, i.e. the impacts on food price and quantity resulting in the market for the food commodity in question and welfare impacts on producers and consumers, are conditional on the assumption that there are no costs involved in reducing food losses and/or waste. If there are costs involved, this has a price increasing effect, with subsequent negative impacts on quantities produced and consumed, and lowering accompanying welfare. This counteracts the initial beneficial impacts of reducing food losses and/or waste.

In the absence of evidence on costs, the impacts that result from an applied analysis of reducing food losses and/or waste should be interpreted as extreme (maximum) impacts and provide boundaries for the allowed costs associated with the loss and/or waste reductions for them to be worthwhile from an economic point of view.

3.4 The causes of food losses and/or waste are likely to matter

The costs that may be associated with reducing food losses and/or waste are very much depending on the measures by which the food loss and/or waste reductions are effectuated. As indicated in the previous analysis, a complicating factor is that losses and/or waste may themselves be influenced by certain factors, such as market scale or the height of food prices.

If these are not addressed, they may make the measures to tackle food losses and/or waste ineffective.[22]

3.5 Consumer preferences matter, but food security may well go up

Abstracting from potential costs involved in reducing food waste, it matters what consumers do with saved expenditures on previously wasted food. If consumers spend it on other non-food commodities, food consumption will generally go down. However, this was previously wasted, so food security in this market remains unaffected. One may even argue that food security improves if one takes into account that the price for the food that is consumed in this market falls. If consumers spend it on other food commodities, then food consumption (and security) will go up, given prices and incomes.

Combatting food losses and/or waste generally is thus likely to enhance food security as food prices will fall and, as a result, food consumption may increase, if not in the market where losses and/or waste are reduced then elsewhere due to increased spending from savings on previously wasted food. The latter is only realised if consumers spend these savings on other food commodities, which depends on consumer preferences.

3.6 Trade-offs arise between actors, markets, countries and over time

The foregoing analysis reveals that various trade-offs may occur.

Firstly, trade-offs may arise between consumers (who generally benefit) and producers (who could lose out). The former will favour actions to combat food losses and/or waste, whereas the latter may object especially when it comes to reducing food waste as this diminishes their revenues.

Producers of other (food or non-food) commodities are, however, likely to welcome reductions in food waste in a different food commodity market as this could imply increased expenditures on their commodities. Hence, also trade-offs and differences in interests between different types of producers are likely to occur.

Given that in the developed world food waste (as opposed to food losses) is dominating and high on the policy agenda, these points are especially relevant in developed countries.

As shown, trade-offs over time are also likely to arise, as in the short-run producers may incur welfare losses when food losses and especially waste are tackled, which may disappear in the long-term. If one accounts for potential costs to be incurred when reducing food losses, this point becomes more important as costs generally need to be borne upfront, whereas the gains, if any, in terms of increased sales may only be realised later. This is an important point for policy makers as food producers may be unwilling to invest given the uncertainty of whether the investment in reducing food losses pays itself back in due time. Timing also becomes important on the demand side, if consumers delay spending savings on previously wasted foods, for example because of market uncertainty or increased costs of living.[23]

How these trade-offs compare to the broader trade-offs between the economic goals of food security (as determined by income and prices) and welfare versus, for example, health and

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[22] If there are costs associated with reducing food losses and/or waste, there may be even an optimal, 'efficient', level of food losses and/or waste. The literature suggests that low food prices may encourage more wasteful behaviour in production and consumption (e.g. BCFN, 2012; p34 and 54), but a waste or loss function has, so far, not been estimated. Future research should look into quantifying or modelling the causes of food losses and/or waste.

[23] Another type of trade-off that may occur, not addressed in this low-dimension partial equilibrium framework, is that between different countries, notably developed and developing countries (see also the introduction). This is best investigated empirically, using an applied model encompassing the global economy.

environmental goals is up to policy makers to decide. It may, for example, be considered worthwhile to tackle food losses and incur associated costs for producers (and consumers for that matter) simply because of the potential environmental benefits. Vice versa, if it is found that, as a consequence, meat consumption increases significantly, with negative health and environmental impacts, policy makers could decide to allow for some waste in food consumption, or apply other measures to reduce the negative health and/or environmental effects (e.g. combine reductions in food losses and/or waste with policies towards a more healthy diet).

Conclusions

This paper analyses the economic impacts of reducing losses in food supply and waste in food demand using standard economic theory of demand and supply.

Using simple diagrams, we show that combatting food losses and/or waste leads to a fall in the price of the food commodity in question, whereas the traded quantity in the market could rise or fall depending on whether, respectively, the food loss or food waste reductions dominate. In terms of welfare, consumers are generally better off when food losses and/or food waste are reduced, whereas producers of the food commodity in question could be worse off, and again this is more likely if reductions in food waste dominate. The welfare losses, if any, will be counteracted by welfare gains for producers and consumers in other commodity markets that are likely to benefit from increased spending of consumers using their savings on previously wasted food. Combatting food losses and/or waste generally may enhance food security as food prices will fall and, as a result, food consumption may increase, if not in the market where losses and/or waste are reduced then elsewhere due to increased spending. The latter is only realised if consumers spend the savings on previously wasted food on other food commodities, which depends on consumer preferences.

The findings are conditional on the assumption that food losses and/or waste are avoidable and that there are no costs involved in reducing food losses and/or waste. Costs have a price increasing effect, with subsequent negative impacts on quantities produced and consumed, and lowering accompanying welfare. In the absence of evidence on costs, the impacts that may result from an applied analysis should be interpreted as extreme (maximum) impacts, providing boundaries for the allowed costs associated with the loss and/or waste reductions.

The analysis has revealed trade-offs between consumers (who generally benefit) and producers (who could lose out) of food, and between producers of food and non-food commodities (other producers potentially benefitting from increased expenditures on their commodities). Trade-offs also arise over time, as in the short-run producers may have to incur costs and welfare losses when food losses and/or waste are tackled, and consumers may delay spending savings on previously wasted foods. How these trade-offs compare to the broader trade-offs between economic, health and environmental goals is up to policy makers to decide.

A full-fledged applied economic analysis encompassing the global economy and interactions between the various actors and markets, i.e. a Computable General Equilibrium type of analysis, may give useful insights into the trade-offs, which benefits the information base for policy makers. It may also shed light on trade-offs that may occur across countries, notably between net food consumers and net food producers, which could reveal whether or not efforts to reduce food losses and especially waste in the developed world benefits food security in developing countries. Future research should also look into quantifying the causes of food losses and/or waste, including scale and price, reveal information on the costs of reducing food losses and/or waste, the extent to which it may be reduced in the first place, and consider the influence of consumer preferences.

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APPENDIX A1 Impacts of reducing food losses under perfectly (in)elastic demand or supply

Figure 1a: Perfectly inelastic demand

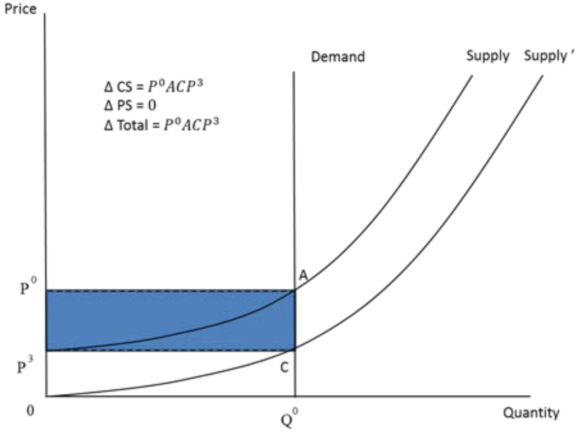


Figure 1b: Perfectly elastic demand

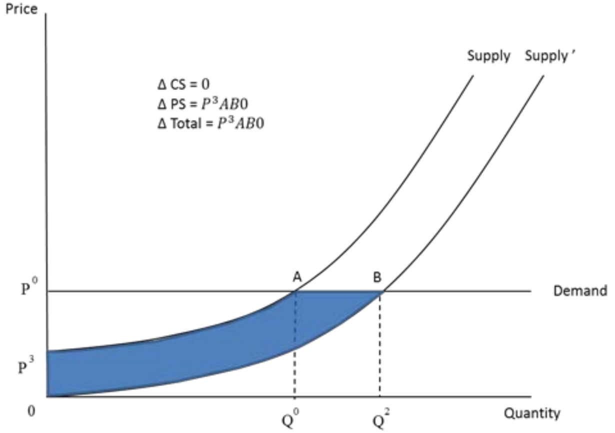


Figure 1c: Perfectly inelastic supply

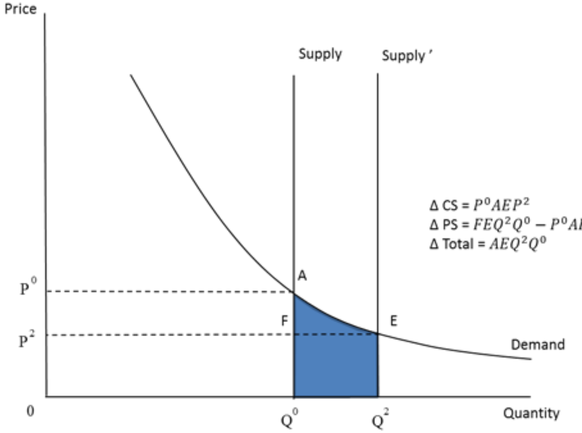
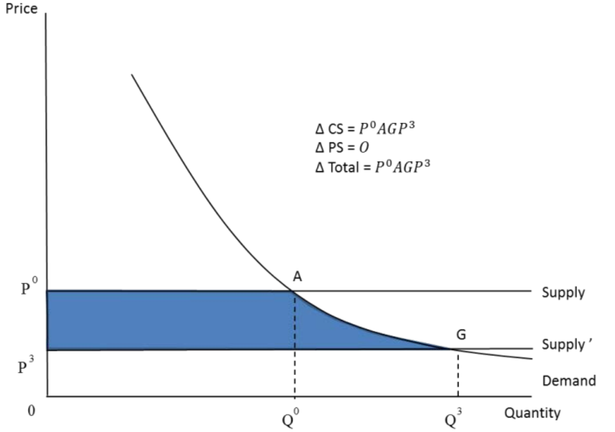


Figure 1d: Perfectly elastic supply



Note: 'Δ' indicates the change in the variable that follows; 'CS' stands for consumer surplus; 'PS' stands for producer surplus; 'Total' stands for the consumer and producer surplus combined.

APPENDIX A2 Impacts of reducing food waste under perfectly (in)elastic demand or supply

Figure 2a: Perfectly inelastic demand

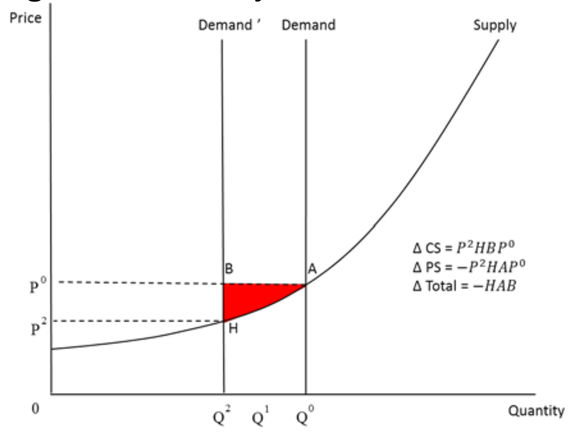


Figure 2b: Perfectly elastic demand

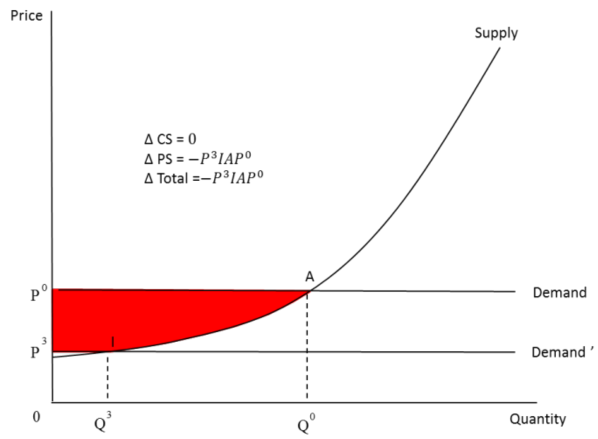


Figure 2c: Perfectly inelastic supply

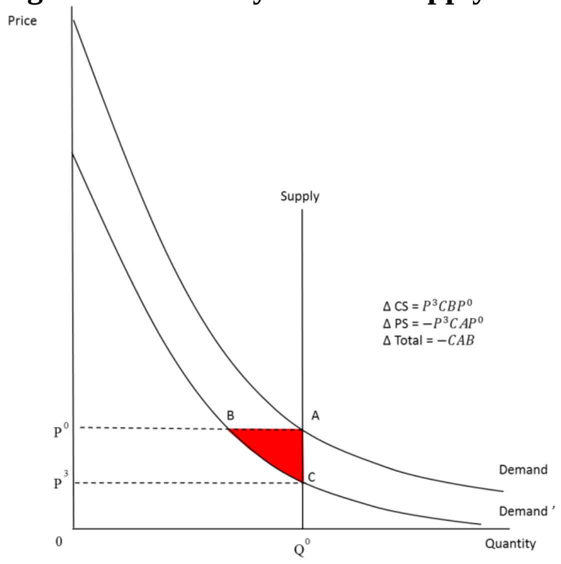
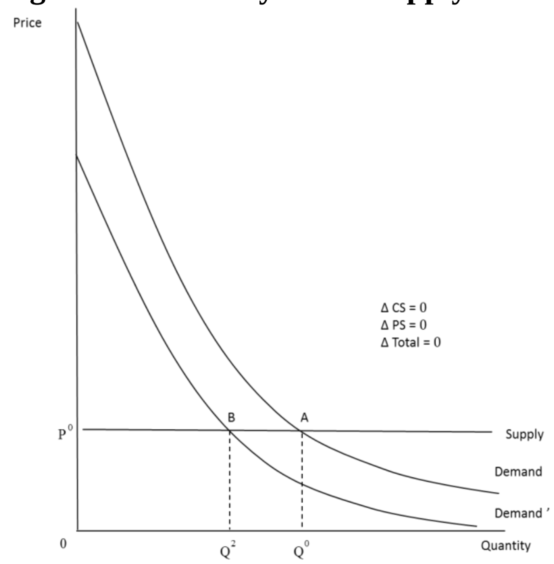


Figure 2d: Perfectly elastic supply



Note: 'Δ' indicates the change in the variable that follows; 'CS' stands for consumer surplus; 'PS' stands for producer surplus; 'Total' stands for the consumer and producer surplus combined.