Economy-wide Impacts of Food Waste Reduction: A General Equilibrium Approach

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Abstract

Food waste has been started to be recognized as an important factor threatening a sustainable food system. However most of the studies in the literature ignore the costs of reducing food waste. In this study we develop a framework to analyse the effects of food waste reduction on the whole economy when associated costs are taken into account in a regional CGE model. Our results suggest that the level of cost is quite important on determining the final impact. Food waste reduction may cause severe loss of competitiveness for agriculture and food production if costs are not taken into account.

Key words: Food waste, Regional Modelling, CGE Modelling, Leisure – Labour trade-off

1. Background

Two recent studies by Monier et al. (2010) and FAO (2014) have shed a light on the severity of food waste. According to Monier et al. (2010), around 90 million tons of food is wasted annually which correspond to 12% of the total food production. Accordingly, food waste has been started to be recognized as an important factor threatening a sustainable food system and EU is not prone to this problem. Consequently, halving the food waste throughout the EU by 2020 is set as a milestone by the European commission to make Europe more resource efficient and to increase the global food security (Monier et al., 2011). Hence, policies aiming at reducing the food waste are likely to be among important drivers of the changes in agrifood sector.

Avoiding food waste is a major concern for the policy makers but it is not possible to avoid food waste all together. Avoidable food waste consists of food that is thrown away but is edible prior to disposal. Unavoidable food waste, on the other hand, arises during food preparation and is not edible under normal circumstances such as egg-shells, bones, etc…). Share of avoidable food waste is estimated to be around 60% of total food waste. Hence in this paper we refer only to the avoidable food waste and ignore unavoidable food waste.

Food waste is defined as discarding raw or cooked food materials at any stage of the supply chain and consumption. Hence it consists of waste generated by households before, during or after food preparation as well as wasted raw and cooked food by farms, retailers, food processing companies, and restaurants etc… Food waste is categorized in 4 broad groups according to where it occurs, i.e. the source of waste: Agricultural sector, households, food processing, retail and food services sectors. 42% of the waste is done by households while 39% is in food processing, 5% in retail and 14% in food services sectors (Monier et al., 2010).

Food waste is linked to several environmental issues such as the landfill expansion and methane emissions that contribute to climate change. Considering the fact that food production activities is responsible around 30% of the global warming potential (EC, 2010), more efficient use of resources can significantly contribute to climate change mitigation and adaptation efforts.

Lastly, food waste causes concerns about the world's hunger problems where 11.3% of people on the world do not have access to enough food to sustain a healthy active life. Better management of the food supply chain to avoid food waste is one of the most important policy options to fight against the global hunger problem (FAO, 2014).

Adding up all these concerns makes it inevitable to develop policies to reduce avoidable food waste. However, as it is in all policy issues, cost of eliminating the food waste is not negligible. From an economic point of view, all markets where food waste occurs are in an equilibrium which allows the current level of food waste to occur. Hence, necessary incentive mechanisms need to be created by policy makers to move these markets to a new equilibrium with less food waste which will imply a different and possibly better allocation of resources throughout the economy and result in a different pattern of production and consumption. Thus, analysis of probable impact of these policies on the whole economy is indispensible to design socially acceptable and sustainable policies.

We employ a modified version of RegCgeEU+ model for this purpose. RegCgeEU+ is a comparative static CGE model that consists of 250 NUTS-II regions in EU explicitly at member state level by using the regional SAMs with the base year 2005. The model consists of 11 production activities producing 11 commodities for a single type of representative household in each region by using labour, capital, land and intermediate inputs. Migration within member states, endogenous employment rate and capital stock, differentiation of regional, national and imported intermediate input use are among the novel properties of the model.

We simulate three scenarios where households, farmers and food producers are forced to reduce their raw and processed food inputs by using more production factors, i.e. labour, land and capital. We, then, look at the impacts on production patterns and household welfare to show the importance of the costs related to food waste reduction. Finally we try to develop policy suggestions that would reduce the costs of food waste reduction.

2. Methods and data

The literature on food waste and losses is recently becoming increasingly popular and covering many fields from engineering to sociology (Evans, 2012) with quantitative and qualitative (Graham-Rowe et al., 2014) analyses. The majority of economic studies and reports on this topic refer to estimation of amount of food waste (i.e., FAO, 2011, Buzby et al., 2014) and possible strategies to reduce it (i.e., Parfitt et al., 2010). They mainly concentrate on the benefits, in terms of possible household monetary savings, related to food loss and waste reduction. They provide estimates in terms of possible input saved (irrigation water, cropland) in case of food waste reduction or elimination, or possible reutilisation of saved output (food production saved which could contribute to food security of unsecure countries, greenhouse gas emission reduced). On the other hand, very little attention is paid to different sources of food waste/losses (post-harvest, food industry, retail sector, households) and almost no consideration is paid to possible cost incurred to achieve such abatement (investments to change or improve technologies or packages, time dedicated to cook at home). Finally, possible impacts on other sectors, particularly the agricultural one, whose price and output will be influenced by reduction of food demand, are not taken into account by the current literature.

The economic literature on the topic does not help in understanding the real economic impacts of possible food waste. As correctly pointed out by Rutten at al. (2013), calculating impacts is different than translating one-to-one food waste losses reduction into inputs savings or output reduction. This ignores interactions between the demand and the supply side of the economy, substitution effects, vertical interlinks among sectors and the role of price mechanisms in an economic system.

On the other hand, when these latter criticisms have been taken into account the reduction in waste has been modelled in a rather simplistic way, i.e. as improvement of productivity without taking into account associated costs. One of the very few studies which empirically investigates the impacts of abatement in food losses adopts a global CGE frame (MAGNET) to analyse the effects of a food loss reduction in Middle East North African (MENA) countries (Rutten and Kavallari, 2013). In absence of evidence on cost of food loss abatement, they introduce food loss as total factor productivity (TFP) shock in the agricultural and fishing sectors by improving efficiency in agricultural production and post-harvest handling and storage, assuming that reducing food losses is costless. These shocks bring a lower production costs for primary agricultural sectors, due to improved efficiency in the use of all inputs, including land. This benefits all primary agricultural sectors which expand. Given the absence of costs, these results provide an upper bound on potential of food loss abatement on food security in the MENA region.

Irfanoglu et al. (2014) investigate the impacts of reducing global food loss and waste on food security, international trade, GHG emissions and land use employing the partial equilibrium (PE) Simplified International Model of agricultural Prices, Land use and the Environment (SIMPLE). The approach implemented by Irfanoglu et al. (2014) also introduces two new dummy production sectors, namely 'post-harvest sector' and 'household production' sectors. The former uses crop and livestock sectors together with a dummy input called post-harvest input while the latter employs household labour and household food purchases. The food loss in post-harvest sector is determined by the level of post-harvest input and the level of food waste is determined by the difference between household food purchases and household food production. This approach is similar to our approach in the sense that they also endogenize the amount of food loss and food waste, by taking the household labour used for food preparation into account. Irfanoglu et al. (2014) do not present any results.

Object of this paper is to overcome the current flaws of economic literature on food waste. First of all, we try to understand which are the possible costs associated with reduction of food waste, avoiding to model food losses abatement only through exogenous efficiency improvement (manna from heaven). Secondly, we analyse the market feedbacks linked to food losses abatement, focusing on the linkages between food waste abatement and the agricultural and food sectors. Additionally, we differentiate different origins of food waste: household, food production and services such as hotels and restaurants. Finally, regional differentiation at NUTS-II level is also taken into account.

3.1 The regionalized CGE Model REG-CGE

We apply the regionalized, single country open economy CGE model REG-CGE (Britz, 2014) developed in the CAPRI-RD project as part of the CAPRI modelling system (Britz and Witzke 2012), based on a regionalised CGE for Finland (Rutherford and Törmä, 2010; Törmä, 2008). Each EU Member State is represented by one open comparative-static economy model that comprises sub-models at the NUTS 2 level. The links between these regions are based on three major mechanisms: distribution of national government income to regional governments; interlinked international, national and regional markets, and finally, net migration functions for population.

These regional CGEs encompass the agriculture, forestry, and other primary sectors, food processing, manufacturing, energy, construction, trade and transport, hotels and restaurants, education, and other services. The primary factors of capital, labour, and land are distinguished, with the latter used in agriculture and forestry. There are four domestic agents in the model. Each region had one utility maximising representative consumer (regional household) that owns the primary factors and draws from them the factor income. Deducting taxes (local and national income taxes) and adding income subsidies from the local government and net-borrowing from abroad to the factor income yields the total household income, which is used for the final consumption of commodities according to a Linear Expenditure System (LES) and saving. Firms maximise profits under the condition of constant returns-to-scale in competitive markets. According to the underlying symmetric Input-Output tables, each sector produces one matching output. The production technology is based on nested Constant Elasticity of Substitution (CES) functions, which describe substitution between the primary factor aggregate and intermediates, and between primary factors. Intermediate input coefficients aggregated over the three origins are based on Leontief. National and regional governments do not participate in production but draw revenues from direct and indirect taxes, which are spent on regional government consumption according to a LES, subsidies, transfers and savings. The national government acts as a tax collector (production tax, sales tax (VAT), investment tax, primary factor tax, and national income tax) and distribution agency and net-borrows from abroad and funnels its revenues to the regional governments. The regional governments draw local income tax and receive their share of the central government revenue plus transfer from the EU for the RD measure. The revenue is distributed in the form of subsidies paid to local households, final consumption (demand of government) according to a LES, and savings. The savings of the regional household and government must be equal to the investments in commodities at the regional level.

The Dixon-Parmenter-Sutton-Vincent (DPSV) investment rule (Dixon et al., 1982) was used to endogenise the total regional capital stock while steering its distribution to the sectors, overcoming one severe shortcoming of comparative-static CGE analysis. According to that mechanism, a change in regional investment demand updates regional sectoral capital stocks and thus impacts production possibilities. Regional labour supply is modelled via a wage curve approach which endogenises the employment rate. The total regional labour stock depends on population size which is endogenously updated based on regional net-migration functions which are driven by regional per capita income and regional unemployment rates in relation to national ones.

The model distinguishes between regional markets, a national market, and imports and exports, to which final demand (investment demand, final consumption by the regional households and government) is distributed based on an Armington approach. Similarly, sectors distribute their outputs to these three levels according to a CET -approach. The intermediate input coefficients for each industry are also disaggregated to the regional, national, and international levels to capture regional multiplier effects; intermediate input demands from these levels substitute according to a CES function. International import and export prices are driven by an iso-elastic function depending on import and export quantities. In our version, the trade balance is closed by the exchange rate at unchanged net-borrowing from abroad (by regional households and the national government). Local government and household accounts are closed by adjusting investment and consumption according to given fixed saving rates and the demand function. The national government account is closed by adjusting tax distribution to the regional governments.

The data collection and fusion process used to cover the whole EU proved challenging. The required regional SAMs, which are the data basis for the regional CGEs, were constructed by combining a limited set of more aggregated regional data from different domains (statistics on employment, GDP by sector, agricultural statistics, in some selected cases regional IO-Tables) in conjunction with national SAMs and estimation approaches (Ferrari et al., 2010; Kuhar et al., 2009) and are currently available for 2005.

3.2 Extensions to cover food waste

In order to model impact of changes in food waste we differentiate between the industry and household level. At industry level, we assume profit maximizing behaviour. Food waste hence reflects at the one hand the existing technology, e.g. the costs of cool chains, and on the other might be the outcome of regulatory restrictions (e.g. certain parts of the carcass cannot be used in production). We come back to that line of argumentation when we discuss our exemplary scenario layout.

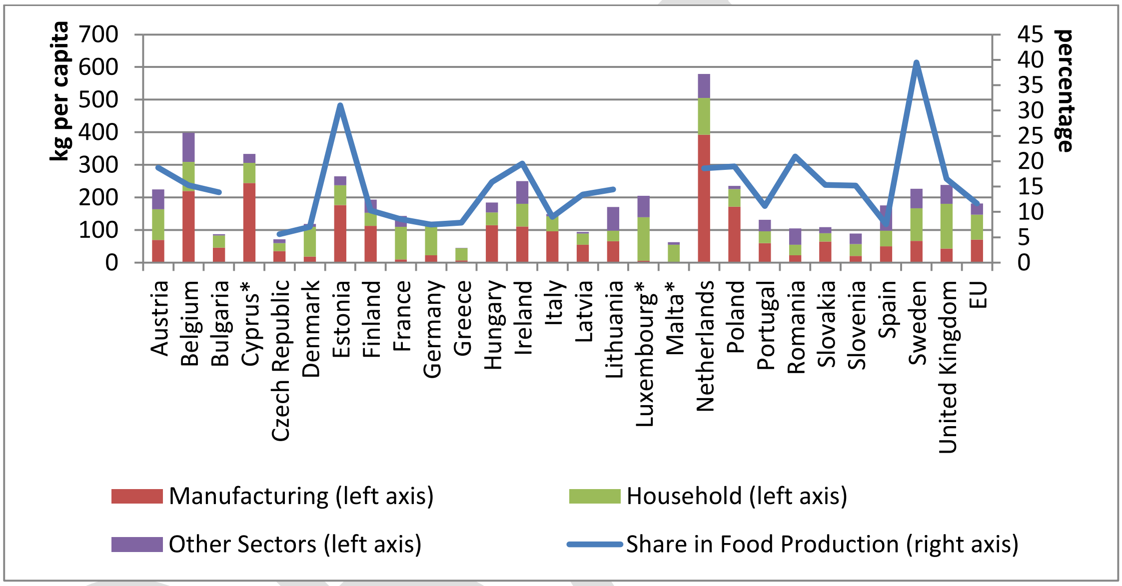
Conceptually, the occurrence of food waste at household level might express preferences for a certain quality of food, such that e.g. specific parts are not used or part of purchases thrown away after they had been stored for a while. Food waste of that kind might hence to some extent reduced by changing preferences. That could be modelled by simply assuming that the same amount of food bought delivers a higher utility. Accordingly, a recalibration of the demand system could be used which would result in a shift away from food consumption to other sectors. We refrain in here from that solution as it does no longer allow for a welfare analysis as two different preference structures would underlie the results.

Instead, we assume that efforts are household level are required to reduce food waste such that the current level of waste is the outcome of a “rational” choice at given preferences. A few examples might motivate that methodological solution. Waste is partly linked to storage times at household level: part of the food might no longer be considered palatable after a while and is thrown away. In order to reduce storage times or to reduce the impact of storage on quality, household might need to shop more often or to remove parts affecting the quality early and more carefully. Food waste might also be avoided by spending more time on food preparation, e.g. to peel fruits and vegetables more carefully, or to prepare dishes from not completely fresh products (e.g. to use old cheese on a gratin, prepare a soup from vegetables).

We hence need to consider endogenous activities at household level, which one could term as “household production”. Similar to the use of intermediates in other sectors, the household transform products bought from the agricultural or food processing sectors in combination with other inputs such as energy and outputs from manufacturing (a refrigerator, stove ...) to food he finally consumes, and these transformation processes require time. That time competes at the one hand with paid for work generating income and at other hand with leisure. Assuming that time can be allocated freely, is marginal “value” product must be equal between these different uses. Technically, we introduce a “cooking” sector in the SAM whose output is not taxed which requires besides intermediate inputs solely labour, which again is not taxed.

We use the food waste estimates of Monier et al.to calculate the size of the shocks (Figure 1). Total food waste in EU adds up to 181 kg per capita of which 39 percent is generated by manufacturing, 42 percent by households and 19 percent by other sectors. This corresponds to 11.6 percent of total food production in EU. Highest food waste is generated in Netherlands, Belgium and Cyprus in per capita terms while share of food waste in total food production is highest in Estonia, Sweden and Ireland. Food waste in Netherlands is more than 3 times the EU average in per capita terms and amounts up to 580 kg. per capita. 67.8 percent of this waste is generated by manufacturing sector while households generate 19.4 percent and other sectors generate 12.7 percent. Total food waste in Netherlands adds up to 19 percent of food production compared to the EU average of 12 percent.

Figure 1: Food waste in EU-27 (kg per capita, 2006)



* Food production data is not available for these countries for 2006
Source: Authors'calculation from Monier et al. (2010)

Introduction of endogenous production activities for cooking and leisure requires modification of the regional SAMs with household time use data. Our strategy for this purpose is first to calculate share of these activities in total household time use and then valuing them by the current wage rate in that region. That is, we assume that households' labour endowment also consists of the leisure time and time spent for cooking.

We apply this approach to Netherlands at NUTS-II level where time use data is readily available from the LISS data base (Scherpenzeel and Das, 2010). The LISS panel consists of household and individual data collected monthly through Internet surveys and covers "a large variety of domains including work, education, income, housing, time use, political views, values and personality" (Scherpenzeel and Das, 2010).

The LISS time use data is consists of 7305 individuals who live in 4555 households. We exclude the time spent for listening to music from the leisure time since average time for listening to music indicates that it is generally done in parallel to some other activities which can be either work or leisure. We reduce time spent on any leisure activities to 4 hours if the reported values are more than 4 hours, to avoid including outliers and misreported observations. Further, we eliminate any individuals from the sample that report more than 4 hours of cooking. For the remaining observations we calculate the time spent on cooking, leisure and work from the survey data. If the sum of these three exceeds 16 hours daily we recalculate the leisure time as residual. If this calculation results in a negative leisure value we eliminate that observation. We further remove all individuals which reported less than 12 hours of total daily activity of leisure, work and cooking.

All these eliminations leave us with 6839 individual observations in 4357 households. Then we aggregate the individual data for households and calculate the shares of times spent for cooking, leisure and work in the total available time of households as well as the unemployment rate from the survey. The unemployment rate is 4.0 percent, which is very close to the unemployment rate for the whole country, indicating the representativeness of the sample. According to our calculations, households in Netherlands spent 6.4 percent of their time for cooking, 39.0 percent for leisure and 54.6 percent for work.

We assume that the value added of labour in the SAM is obtained for the 54.6 percent of households' total available time. Value of labour spent for cooking and leisure is calculated by assuming that value of unit time spent on these activities should be same with the time spent for work. We introduce these values as labour value added created in cooking and leisure sectors. Then we assume that all the labour value added generated by cooking and leisure activities goes to households as income and all output of these sectors are consumed also by households. Note that the share of time spent for leisure and cooking are assumed to be same across NUTS regions. The difference across regions is due to the price of unit time which depends on the regional wage rate. Lastly, we modify the regional SAMs such that 75 percent of agricultural and food consumption and 10 percent of energy consumption of households becomes intermediate input to the cooking activity.

3. Scenario analysis

4.1 Scenario definition

We explore three exemplary scenarios which all change the technology in the food processing industry respectively in household activities:

1. "**Free lunch**" **(FL)**: That scenario makes the rather unrealistic assumption that current food waste share can be simply avoided. That scenario is implemented by reducing the intermediate input coefficient in the food processing industry and at household level by the food waste shares reported in literature. It is hence equivalent to an intermediate input saving productivity shock.
2. "**Tit for tat**" **(TfT)**: Similar to free lunch scenario, we reduce intermediate input coefficient. However, we now calculate the cost saving at benchmark prices, calculate the change in primary factor costs to offset these cost savings, and update the primary cost shares accordingly. That scenario thus assumes a highly flexible technology where food waste can be avoided by using more labour and capital, without changing per unit costs.
3. "**Costly lunch**" **(CL)**: Similar to tit for tat scenario, food waste is avoided by using more labour and capital. However, now, the increase in primary factor is twice as high as the cost saving from reduced intermediate demand (at benchmark prices).

4.2 Results

Scenario results show the importance of the cost of reducing food waste in determining the final impact on the economy. In the "free lunch" (FL) scenario, since economic agents do not bear any costs the impact is quite positive with declining prices in all sectors, increasing demand and production (Figure 1). These effects are significant especially for food processing, agriculture and hotels & restaurants sectors. Although it can look curios why would a reduction in food waste would cause increase in demand for processed food and agriculture, the underlying reason is the fact that the most important users of these sectors' outputs as intermediate inputs is themselves. Hence with the reduction in intermediate input requirements, these sectors become significantly competitive and increase their production despite the fall in the price creating more income for households. Further, together with the savings in intermediate input use of cooking activity (i.e. households use less agrifood products for cooking), households can afford more of these products. As mentioned before this scenario is rather unrealistic and is run to show the fact that, any policy designed without taking into account the costs of food waste reduction is also unrealistic. So in conclusion we can say that "free lunch is too good to be true".

Results of 'tit for tat' (TfT) and 'costly lunch' (CL) scenarios show that the higher the cost the bigger and more negative the impact is. In these scenarios, the first order effect is reduced competitiveness for the cooking, agricultural and food processing sectors. This causes production in these sectors to decline. Even when the value of increase in factor cost is equal to the value of decrease in the cost of intermediate inputs under the TfT scenario, the impact of this change in factor markets and commodity prices results in significantly higher costs of production. Consequently, production in these sectors also declines under "tit for that" scenario.

Table 1: Demand and Production and Prices [percentage change]

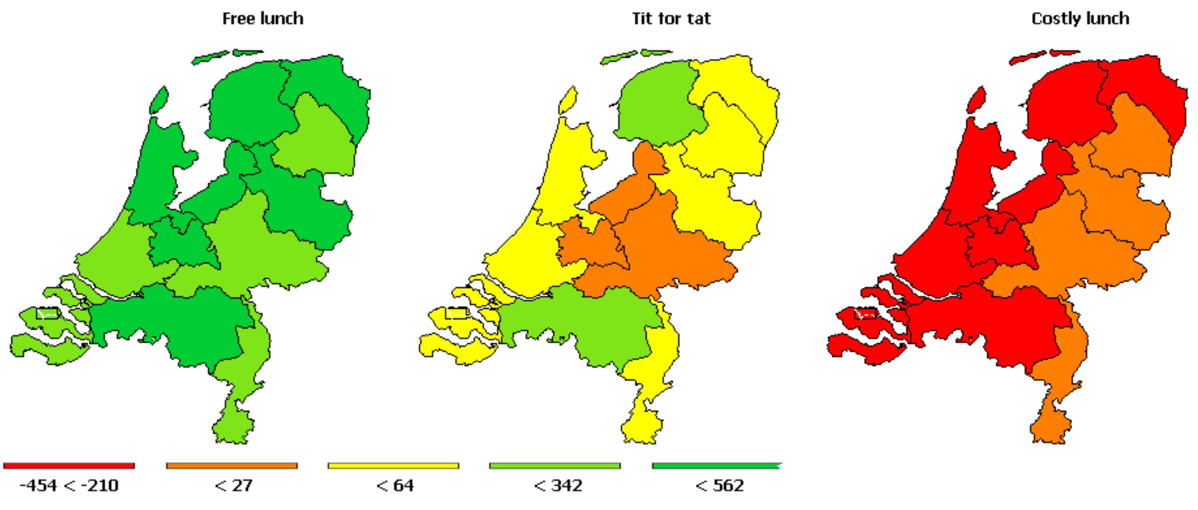
	Consumer Price			Demand			Producer price			Production		
	FL	TfT	CL	FL	TfT	CL	FL	TfT	CL	FL	TfT	CL
Agriculture	-2.0	-0.9	0.1	2.8	1.0	-0.5	-2.3	-0.8	0.5	3.5	-3.7	-8.9
Forestry	-0.8	-0.4	-0.2	0.7	0.2	-0.2	-0.2	-0.6	-0.8	0.4	0.0	-0.3
Oth. pri. Prod.	-1.4	-0.5	0.1	3.1	0.9	-0.6	-1.3	-0.6	-0.2	-0.7	0.0	0.5
Food proc.	-6.2	-0.5	4.0	5.3	0.5	-2.7	-6.3	-0.1	4.9	6.5	-7.7	-16.8
Other manu.	-1.2	-0.4	0.1	1.5	0.4	-0.4	-1.3	-0.5	0.0	-0.7	-0.1	0.4
Energy prod.	-1.0	-0.5	-0.3	1.6	0.5	-0.2	-1.3	-0.6	-0.1	0.4	-0.2	-0.7
Construction	-0.5	-0.3	-0.2	1.3	0.4	-0.2	-0.6	-0.4	-0.3	1.0	0.3	-0.2
Trade & trans.	-0.5	-0.4	-0.4	1.1	0.4	-0.1	-0.9	-0.5	-0.2	0.1	0.0	-0.1
Hotel & rest.	-2.1	-0.3	1.1	2.3	0.3	-1.1	-2.5	-0.3	1.5	2.0	0.1	-1.4
Education	-0.4	-0.3	-0.3	0.2	0.0	-0.2	-0.5	-0.4	-0.3	0.1	-0.1	-0.2
Other serv.	-0.5	-0.4	-0.3	0.8	0.2	-0.2	-0.7	-0.4	-0.3	0.4	0.0	-0.3
Cooking	-0.3	1.2	2.7	1.4	-0.7	-2.6	-0.3	1.2	2.7	1.4	-0.7	-2.6
Leisure	0.9	0.2	-0.4	0.5	0.1	-0.2	0.9	0.2	-0.4	0.5	0.1	-0.2

Source: Model results

In TfT scenario, demand for cooking declines while demand for agriculture and food is still increasing together with all of the remaining sectors. Noting that production of agricultural, food processing and cooking sectors declines, significantly for the first two, and relatively mildly for the latter while demand for hotels &restaurant services are increasing, it can be concluded that the increasing cost of cooking at home is likely to cause households to eat out more.

The welfare implications of the food waste reduction generally follow the expected patterns. As expected, all regions benefit from food-waste reduction when there is no trade-off while the gains decline under TfT scenario and becomes negative for all regions under CL scenario. The change in the ranking of regions in terms of gains and losses across scenarios exhibit an interesting pattern (Figure 2). When there is no cost, Flevoland is the most benefiting region with per capita equivalent variation (EV) of €582. However, with the introduction of costs, this regions is least winning region under TfT with €14 per capita EV and most losing region under CL scenario with per capita EV of € -468. On the other hand, other most benefiting regions Noord-Brabant, Friesland and Noord-Holland keep their ranking in welfare gain ranking under FL while Limburg ranks close to the median. In general, the most benefiting regions become the most losing regions with the introduction of trade-off between food input savings and factor use. Hence it is important to take into account regional differences in designing food waste policy.

Figure 2: Per capita equivalent variation across regions (2005 Euros)



Source: Model results

4. Conclusions

In this paper we presented a promising framework in the analysis of food waste in the computable general equilibrium context. Our approach allows analysing the role of trade-off between time spent on food preparation and savings in food inputs used; both at the household and at the industry level. However the approach can be easily extended to analyse other issues related to the food waste policy such as recycling, taxation, health issues environmental issues etc...

It is obvious from the scenario results that the lower the cost of food waste reduction, the more the economy benefits from it. Hence an important pillar for the policies targeting to reduce food waste is reducing its costs, economy wide. The trade-off between the time spent for food production and reduction in food waste turns out to be a crucial component of these costs. Identification and quantification of this trade-off is crucial to be able to address them properly. Once identified, policies to loosen this trade-off such as encouraging technological improvements that would simultaneously save food and time spent in food preparation at the household level and in the food processing industry turns out to be crucial.

Obviously this study is not prone to deficiencies. A more detailed framework would food-saving technologies would extend to our analysis to more concrete policy suggestions. Then, linking these technologies to the trade-off between time used for food preparation and food waste reductions quantitatively and explicitly in the model would be a natural extension. Another direction for future research is extending the spatial coverage of the study to whole EU-27 would allow us to make policy suggestions at the European level. The latter would be important to differentiate and prioritize the policies and investments according to the needs of each NUTS-II region. Lastly, although we are using the most recent estimates by Monier et al. (2010), a sensitivity analysis for the level of food waste would give more insight on many aspects of the problem.

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