

Economic impact assessment of food waste on European countries throughout Social Accounting Matrices

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**PILAR CAMPOY-MUÑOZ
M. ALEJANDRO CARDENETE
M. CARMEN DELGADO**

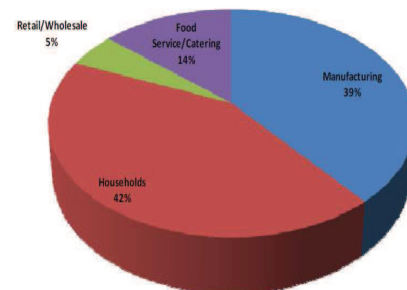
OUTLINE

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MOTIVATION

FOOD WASTE

- **A major global issue, which threatens a sustainable food system and generates negative externalities in environmental terms.**
- **Composed of raw or cooked food materials and food discarded along the supply chain and household level.**
- **Around 90 million tonnes of food waste are generated in the EU each year.**



Source: European Commission Report (2010)

GOAL OF THE STUDY

“Assessing the effects of food waste reduction on national economies in terms of total output, GDP and employment”

- Which is the total impact of food waste reduction?
- Which is the impact of food waste reduction by the previous agents?
- Which is the impact of food waste on the total output agrifood accounts (sector which produces food)?

METHODOLOGY: LINEAR MULTIPLIERS MODELS

Brief explanation of these models, as an extension of the Leontief Model:

$$Y_i = \sum_{j=1}^n (Y_{ij}/Y_j) Y_j = \sum_{j=1}^m a_{ij} Y_j + \sum_{j=m+1}^{m+k} a_{ij} Y_j, \quad n = m + k \quad (1)$$

$$dY_m = MdZ = Md(A_{mk} Y_k) = MA_{mk} dY_k \quad (2)$$

Agricultural Social Accounting Matrices for the case of studies: Germany, Spain and Poland.

- **Agrosam 2007**: IPTS, European Commission. (2012).

Structure

- | | |
|---------------------|-----------------------|
| * 87 activities | * Enterprises |
| * 96 commodities | * Investment |
| * 2 primary factors | * Public sector |
| * 12 Taxes | * Foreign sector |
| * Consumer | Total: 214×214 |

SCENARIOS

Five different scenarios:

- Following European Commission report (2010) the distribution of food waste was then made, breaking down food waste by Manufacturing (39%), Household (42%), Retail (5%) and Food Service (14%) sector data.
- With these percentages breakdown of EU27, it is necessary to establish the avoidable portion of this food waste. This study quantifies them as a follow:
 - 1) Households: Food which ends up as being discarded by households represents 25% of food purchased (by weight), and the avoidable portion of this food waste represents 60%.
 - 2) Manufacturing: Food waste at this level is largely unavoidable (bones, carcasses and certain organs in meat products for example), so it is not necessary to establish shock on this account.

SCENARIOS

3) Food services: In the Food Service sector, 4% to 10% of food purchases are estimated to become waste before reaching a customer, so the midpoint is established in this study (7%), and the avoidable portion of this food waste represents 90%.

4) The Wholesale/Retail sector: This is defined as generating the smallest proportion of food waste at 5%, is also the area where data is the most scarce.

- Given that there is information available on the amounts of food waste across European Union, the distribution of food waste and the rate of waste by weight (European Commission, 2010), five initial scenarios are set out based on the four selected countries (Germany, Spain and Poland).

SCENARIOS

S1: Total impact of Food waste in total output, GDP and employment. Impact on Spanish, German and Poland economies are analyzed as a result of total waste (households, food services and wholesale/retail sector).

S2: Impact of Food waste in the wholesale/retail sector in total output, GDP and employment.

S3: Impact of Food waste in the food service sector in total output, GDP and employment.

S4: Impact of Food which ends up as being discarded by households in total output, GDP and employment.

S5: Total Impact of Food waste in total output on agrifood accounts.

RESULTS

Scenario 1

| GERMANY | | SPAIN | | POLAND | |
|------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|
| Total Shock | | Total Shock | | Total Shock | |
| -29,968 | | -12,742 | | -6,868 | |
| Total impact in production /income | Percentage change after shock | Total impact in production /income | Percentage change after shock | Total impact in production /income | Percentage change after shock |
| -48,563.53 | -1.42 | -24,145.97 | -1.57 | -11,448.09 | -2.32 |
| Total impact in terms of GDP | Percentage change in GDP after shock | Total impact in terms of GDP | Percentage change in GDP after shock | Total impact in terms of GDP | Percentage change in GDP after shock |
| -18,134.76 | -1.21 | -9,669.65 | -1.49 | -4,185.58 | -2.15 |
| Change in labor after shock | | Change in labor after shock | | Change in labor after shock | |
| -323,582.27 | | -162,323.37 | | -183,380.96 | |

Source: Authors

RESULTS

Scenario 2

| GERMANY | | SPAIN | | POLAND | |
|------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|
| WTRD-RTRD Shock | | WTRD-RTRD Shock | | WTRD-RTRD Shock | |
| -72.67 | | -108.77 | | -246.95 | |
| Total impact in production /income | Percentage change after shock | Total impact in production /income | Percentage change after shock | Total impact in production /income | Percentage change after shock |
| -782.52 | -0.02 | -1,260.62 | -0.07 | -1,838.02 | -0.33 |
| Total impact in terms of GDP | Percentage change in GDP after shock | Total impact in terms of GDP | Percentage change in GDP after shock | Total impact in terms of GDP | Percentage change in GDP after shock |
| -370.05 | -0.02 | -590.45 | -0.07 | -772.62 | -0.32 |
| Change in labor after shock | | Change in labor after shock | | Change in labor after shock | |
| -6,399.87 | | -11,378.29 | | -36,580.61 | |

Source: Authors

RESULTS

Scenario 3

| GERMANY | | SPAIN | | POLAND | |
|------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|
| Food Services Shock | | Food Services Shock | | Food Services Shock | |
| -1,602 | | -1,165 | | -187 | |
| Total impact in production /income | Percentage change after shock | Total impact in production /income | Percentage change after shock | Total impact in production /income | Percentage change after shock |
| -10,450.98 | -0.28 | -6,934.86 | -0.41 | -1,684.07 | -0.30 |
| Total impact in terms of GDP | Percentage change in GDP after shock | Total impact in terms of GDP | Percentage change in GDP after shock | Total impact in terms of GDP | Percentage change in GDP after shock |
| -4,613.71 | -0.27 | -2,994.03 | -0.40 | -690.20 | -0.30 |
| Change in labor after shock | | Change in labor after shock | | Change in labor after shock | |
| -75,989.38 | | -54,615.69 | | -29,915.10 | |

Source: Authors

RESULTS

Scenario 4

| GERMANY | | SPAIN | | POLAND | |
|------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|
| Households Shock | | Households Shock | | Households Shock | |
| -28,293 | | -11,468 | | -6,434 | |
| Total impact in production /income | Percentage change after shock | Total impact in production /income | Percentage change after shock | Total impact in production /income | Percentage change after shock |
| -68,688.45 | -1.52 | -30,548.80 | -1.47 | -16,763.42 | -2.65 |
| Total impact in terms of GDP | Percentage change in GDP after shock | Total impact in terms of GDP | Percentage change in GDP after shock | Total impact in terms of GDP | Percentage change in GDP after shock |
| -29,647.68 | -1.36 | -13,569.28 | -1.36 | -6,958.15 | -2.48 |
| Change in labor after shock | | Change in labor after shock | | Change in labor after shock | |
| -576,486.73 | | -259,869.57 | | -332,327.08 | |

Source: Authors

RESULTS

Scenario 5

| | GERMANY | | SPAIN | | POLAND | |
|----------------|------------------------------------|-------------------------------|------------------------------------|-------------------------------|-----------------------------------|-------------------------------|
| | Total impact in production/ income | Percentage change after shock | Total impact in production/ income | Percentage change after shock | Total impact in production/income | Percentage change after shock |
| 1 A_OWHE | -326.47 | -7.60 | -148.64 | -10.60 | -223.61 | -11.78 |
| 2 A_DWHE | -0.91 | -11.35 | -34.59 | -7.99 | 0.00 | |
| 3 A_BARL | -119.29 | -5.71 | -193.83 | -6.67 | -78.92 | -9.45 |
| 4 A_MAIZ | -64.79 | -7.25 | -77.87 | -7.61 | -38.58 | -9.66 |
| 5 A_OCER | -81.20 | -7.29 | -29.08 | -7.47 | -219.81 | -8.92 |
| 6 A_PARI | 0.00 | | -19.36 | -7.30 | 0.00 | |
| 7 A_RAPE | -91.97 | -4.68 | -0.67 | -6.00 | -28.39 | -3.75 |
| 8 A_SUNF | -1.21 | -5.36 | -24.95 | -6.97 | 0.00 | |
| 9 A_SOYA | 0.00 | | -0.02 | -6.82 | 0.00 | |
| 10 A_OOIL | -0.21 | -6.00 | 0.00 | -7.49 | -5.08 | -13.17 |
| 11 A_STPR | -3.46 | -6.37 | -3.60 | -5.59 | -15.19 | -13.14 |
| 12 A_POTA | -148.74 | -8.64 | -84.24 | -11.11 | -147.07 | -10.23 |
| 13 A_SUGB | -34.20 | -4.13 | -13.51 | -6.23 | -38.03 | -7.52 |
| 14 A_FIBR | 0.00 | | -2.14 | -4.43 | -0.08 | -3.22 |
| 15 A_GRPS | 0.00 | | -81.81 | -10.60 | 0.00 | |
| 16 A_FVEG | -432.47 | -12.34 | -1,201.14 | -7.93 | -374.30 | -12.43 |
| 17 A_LPLT | -132.60 | -4.15 | -197.47 | -8.34 | -23.45 | -12.28 |
| 18 A_OTCR | -14.93 | -2.23 | -61.75 | -4.92 | -14.52 | -8.74 |
| 19 A_FODD | -618.71 | -10.26 | -69.22 | -7.60 | -131.69 | -9.12 |
| 20 A_SETA | 0.00 | | 0.00 | | 0.00 | |
| 21 A_COMI SGMI | -973.62 | -8.88 | -390.86 | -11.24 | -525.80 | -12.21 |
| 22 A_LCAT | -244.50 | -5.86 | -271.86 | -8.60 | -81.39 | -6.20 |
| 23 A_PIGF | -450.31 | -7.42 | -533.90 | -9.12 | -402.73 | -11.59 |
| 24 A_LSGE | -21.06 | -6.10 | -183.12 | -10.59 | -3.37 | -2.82 |
| 25 A_EGGS | -63.40 | -9.80 | -133.68 | -10.58 | -127.64 | -12.98 |
| 26 A_PLTR | -127.28 | -7.07 | -242.72 | -10.41 | -238.15 | -10.68 |
| 27 A_ANHR | 0.00 | | 0.00 | | 0.00 | |
| 28 A_OANM | -15.21 | -4.66 | -1,759 | -5.06 | -5.04 | -8.01 |
| 37 A_RICE | -0.23 | -9.81 | -31.86 | -7.92 | 0.00 | |
| 38 A_OFOD | -8,436.48 | -12.38 | -3,877.00 | -10.79 | -57.15 | -7.46 |
| 39 A_SUGA | -184.62 | -5.30 | -90.91 | -8.03 | -196.05 | -9.68 |
| 40 A_VOIL | -140.10 | -4.51 | -280.56 | -7.02 | -46.55 | -4.99 |
| 41 A_DAIR | -3,197.29 | -10.22 | -1,448.88 | -13.01 | -2,073.73 | -12.56 |
| 42 A_BFVL | -428.59 | -8.58 | -399.74 | -10.71 | -97.21 | -7.40 |
| 43 A_PORK | -740.91 | -9.16 | -680.23 | -10.75 | -476.05 | -12.26 |
| 44 A_SGMT | -36.44 | -10.20 | -364.44 | -12.93 | -5.94 | -5.36 |
| 45 A_POUM | -166.82 | -11.12 | -334.75 | -13.29 | -529.45 | -12.57 |
| 46 A_BEVR | -1,903.46 | -12.25 | -796.94 | -7.38 | -23.18 | -5.94 |
| TOTAL | -19,201.48 | -246.68 | -12,322.93 | -309.1 | -6,228.15 | -276.12 |

Source: Authors

CONCLUSIONS

- ✓ The results show the greatest impacts are due to a reduction on the avoidable portion of the wasted food by household across the countries, but different results in terms of production/ GDP vs employment.
- ✓ Design of policies for food waste reduction in Food services and Wholesale/ Retailers

Future research lines...

- ✓ Extend the analysis to the complete UE.
- ✓ Estimating the economic impact with a CGE model .

**Economic impact assessment of food
waste on European countries throughout
Social Accounting Matrices**



**PILAR CAMPOY-MUÑOZ
M. ALEJANDRO CARDENETE
M. CARMEN DELGADO**

Economic impact assessment of food waste on European countries throughout Social Accounting Matrices

Abstract: Food waste is becoming a major global issue, which threatens a sustainable food system and generates negative externalities in environmental terms. From an economic perspective, studies focus on estimating the amount and monetary value of the wasted food by households and along the supply chain, in order to highlight the associated cost to the society. In this paper we adopt a different point of view, assessing the effects of food waste reduction on national economies in terms of total output, GDP and employment. To do this, we use linear multiplier models based on Social Accounting Matrices with a highly disaggregated agricultural account for the year 2007. The proposed methodology is applied to a sample of European countries with different economic structure, i.e. Spain, Germany and Poland. The results show the greatest impacts are due to a reduction on the avoidable portion of the wasted food by household across the countries.

JEL Classification: C67, D57, Q18.

Keywords: Agricultural Social Accounting Matrix, SAM Model, Bio-waste, Impact Analysis, European Union.

1. Introduction

About one-third of food produced for human consumption gets lost or wasted, becoming a major global issue which threatens a sustainable food system and generates negative externalities in environmental. The patterns of food waste completely differ across the world, where developed countries emerge as the largest food waster, especially at consumer levels. On per capita basis, Gustavsson et al. (2011) estimates that the food waste in Europe and North-America is 95-115 kg year, in contrast with Sub-Sahara Africa or South/Southeast Asia where this figures decreases to 6-11 kg year. Focusing on European Union, this figure amounts 76 g per person and year, which roughly represents 45% of the total food waste in the whole supply chain, excluding agricultural production Monier et al. (2010). In view of this situation, European Commission has set the target of cutting down food waste to one-half by 2020 throughout the European Union (EU). Accordingly, national campaigns against food waste have been launched and governments have led to research to get a deeper understanding of food waste within its borders (Monier et al., 2010; Viel et al., 2008). As a result, most economic reports and studies aim to estimate the amount of food wasted (Gobel, 2012; Hansen, 2013), whereas fewer attempt to estimate its monetary value (Segré and Falasconi, 2011; Williams, 2011) and to a much lesser extent to monetize its social and environmental cost (ARC, 2012; BCFN, 2012). In those cases, two approaches are mainly employed to monetize the economic impact of food waste, focusing on production cost of the food wasted or on its market prices. Both methodologies could be extended to estimate the economic impact on the usefulness of the entire society, including an estimation of the society willingness to pay the price that avoids negative externalities produced by food waste or the opportunity cost of the resources necessary for producing the food wasted. Thus, reducing food waste is intended as benefits for supply chain members, households, and the whole of the society, by translating this reduction into monetary saving.

However, calculating the economic impact of food waste reduction involves more than just a one-to-one translation in savings, it should take into account the interactions between actors and sectors in the food system and in the whole economy (Rutten, 2013). In this vein, the Computable General Equilibrium (CGE) framework becomes a powerful tool for assessing the economic impact of food waste reduction, encompassing demand and supply interactions, the intersectoral linkages, the substitution effects and the role of price mechanism therein. Despite these advantages, few attempts have been made by using non-linear CGE models. A partial CGE model is developed by Irfanoglu et al. (2014) to evaluate the impacts of reducing food loss and waste on social, environmental and trade dimensions without empirical results. A regionalized CGE model for Finland is performed by Britz et al. (2014), in which the economic impact of food waste is assessed, by means of a trade-off between raw or processed food inputs and production factors at farm, food industry and household levels, in order to inform policy design. Finally, a multi-region CGE model (called MAGNET) is employed by Rutten et al. (2013) to simulate EU-2020 target of halving waste in food demanded at household and supply chain members across European Union, offering a comparable set of economic indicators; as well as their impact on third countries (Rutten et al., 2014). The MAGNET model has been also employed for assessing the economic impact of reducing food loss along the different stages of the agriculture supply at Ghana (Rutten and Verma, 2013) and at Middle East and North Africa (Rutten and Kavallari, 2013).

In the vein of the CGE framework, we employ a linear CGE model to address the economic impact of reducing avoidable food waste on a sample of EU countries with different economic structures (Spain, Poland and Germany), and, especially, on their agri-food sector. The impact analysis is addressed under five different scenarios in order to gain a better understanding of waste food reduction along the different levels of the supply chain and also at consumer levels. To do so, a multiplier model is developed upon a Social Accounting Matrix (SAM) with highly

disaggregated agricultural and food industry accounts (AgroSAMs) for the corresponding country member. Each AgroSAM is based on a SAM, which depicts the complete set of relationships among agents in that economy, enlarged with a much more detailed information about raw agricultural products and processed food commodities than the database employed in the aforementioned studies.

After this introduction, AgroSAM database and the SAM-based multiplier models are described in order to gain a better understanding of the empirical application. Then, results are presented in terms of Gross Domestic Product (GDP), Production and Employment, considering both the entire economic setting and the disaggregation by agri-food accounts. The work ends with the main conclusions.

2. Data and methods

2.1. Social Accounting Matrices and the AgroSAM database

SAMs are transparent and efficient devices of the circular income flow of an economy over a period of time by mean a square flow matrix (Stone, 1962). Beside the interindustry transactions specific of Input-Output Tables, SAMs include balanced accounts for factors, institutions, such as producers, consumers, government and foreign sector, and other auxiliary accounts, closing the cycle of the income distribution and spending. In this structure, each row and the corresponding column form an account, which summarizes all the information on the aforementioned economic agents. Rows show sources of their income and columns how these revenues are allocated as expenditures. All the values in the cells are monetary flows; thereby each nonzero value of a cell reflects a transaction between accounts. Given that total income equals total expenditures for every account, the information in a SAM can be interpreted, in some cases, through zero benefit conditions, budget constraints, and market clearing equations.

Thus, SAMs are crucial databases for quantitative models (e.g. SAM linear models and/or Computable General Equilibrium models) and also useful tools to evaluate policy interventions in national or regional frameworks (Roland-Holst, 1990).

In this work SAMs with a detailed agricultural and food manufacturing information, called AgroSAMs, are employed. The AgroSAM database has been constructed based on the National Supply and Use Tables (SUT) of member states provided by Eurostat (Müller et al., 2009), and the corresponding agricultural account were disaggregated based on the database from the “Common Agricultural Policy Regionalised Impact analysis modelling system” (CAPRI) (Britz and Witzke, 2012), a partial equilibrium agro-economic simulation model. The results are SAMs for each member state covering agricultural and non-agricultural activities and commodities, more detailed than previously existing databases employed for agricultural CGE modelling, such as Global Trade Analysis Project (GTAP) Database. For comparison, GTAP dataset, which is employed within MAGNET model, has twelve raw agricultural products and eight processed food commodities. AgroSAM distinguishes eighty seven activities and the ninety six commodities, of which twenty corresponds to primary agriculture, twenty one to primary sector, ten to food industry, twenty nine to manufacturing industry, one to construction and twenty five are commodities of the service sector. In addition, the AgroSAMs contain two production factors (capital and labor), trade and transportation margins, eleven types of taxes and five accounts for institutions (a single representative household, corporation, central government, investments-savings account and rest of the world). This structure has been tailored to the scope of the study with greater emphasis on those accounts that will be analyzed, as shown in Table 1. The original AgroSAMs are for year 2000; whereas the ones employed in this work are updated to the year 2007 (European Commission, 2012). From the complete database, AgroSAMs for Spain, Poland and Germany were chosen to analyze and compare

the economic impact of reducing food waste on these member states, representative of different economic structures.

(Table 1 about here)

2.2. Linear CGE Models

In this work, a linear CGE model is developed upon the multiplier theory initiated by Stone (1962) and Pyatt and Round (1979), which was later further developed by with works such as Defournay and Thorbecke (1984). These methods are based on information, from the inverse matrices derived from the models of Leontief (1941) and Ghosh (1958) applied to the SAM, on the ability of an expanding sector increases demand or costs, respectively.

Following Cardenete et al. (2012), we begin with a brief explanation of these models, as an extension of the Leontief Model: a square $n \times n$ matrix is considered, where each row and each column represent an economic account (productive sectors, consumers, government, capital, etc.) that satisfies the accounting equations of the economy (total income equals total expenditure). Each Y_{ij} component of the matrix represents the bilateral flow between account i and account j . Each row of the SAM reflects the total income that row i receives from column j ; each column shows the total income of column j and how it is distributed among the different i rows. The average expenditure coefficients: $a_{ij} = Y_{ij} / Y_j$, $i, j=1 \dots n$, show the payments made to account i for every income unit of j . From this definition it is possible to obtain:

$$Y_i = \sum_{j=1}^n \left(\frac{Y_{ij}}{Y_j} \right) \cdot Y_j = \sum_{j=1}^m (a_{ij} Y_j) + \sum_{j=1}^{m+k} (a_{ij} Y_j) \quad n = m + k \quad (1)$$

Indexes m and k represent the division of the SAM accounts into endogenous and exogenous accounts, which leads to the division of the $n \times n$ matrix into four submatrices: A_{mm} , A_{mk} , A_{km} ,

and A_{kk} . Y_m and Y_k respectively denote the total income of the endogenous and exogenous accounts. Therefore, it is possible to work out the value of Y_m from $Y_m = A_{mm} Y_m + A_{mk} Y_k$, and then, following the same procedure as with the Leontief equation, calculate the extended multipliers matrix from $Y_m = (I - A_{mm})^{-1} Z$, where Z is the vector of exogenous accounts¹ ($A_{mk} Y_k$) and $M = (I - A_{mm})^{-1}$ is the extended multipliers matrix in the SAM. These multipliers can be interpreted as the input requirements by unit increases of expenditure or income (depending on whether columns or rows are considered) in an account, as in the so-called inverse Leontief matrix, with the difference that this matrix reflects the relation between production, the factors' income, income distribution and final demand. It is important to point out that the selection of m (i.e., the decision regarding which accounts are endogenous) usually depends on the type of analysis undertaken, which determines which accounts (exogenous) are the ones explaining the variation of the income in other accounts (endogenous). If changes in the vector of exogenous accounts are denoted as dZ , changes in the income of the endogenous accounts will be expressed as:

$$dY_m = MdZ = Md(A_{mk} Y_k) = MA_{mk} dY_k \quad (2)$$

The i^{th} column in M indicates the total income generated in each of the endogenous accounts when a unit of income flows from the exogenous institutions towards endogenous account i .

Simulations and results

The aforementioned model is employed to assess the economic impact of reducing avoidable food waste on a sample of European member states, such as Germany, Spain and Poland. To do this, an exogenous vector Z is defined for each agent along the supply chain and at household level, encompassing the corresponding demand of agrifood commodities. A new vector Z' is obtained by subtracting the injection

¹ Submatrix A_{mk} represents how the income flows from the exogenous accounts are distributed among the endogenous accounts.

of income resulting of monetize the avoidable portion of food waste² by each agent along the supply chain and at household level in each member state selected. The breakdown among different agents responsible for food waste is determined by Monier et al. (2010), which does not include the agricultural activities but represents the only current reference when it comes to statements about the extent of food wastage in the EU-27 (Bräutigam et al., 2014). According to this study, the Wholesale/ Retail³ sector (WRS) generates the smallest proportion of food waste, only a 5%, followed by the Food service/Catering⁴ sector (FCS), which amounts for a 14% of the waste. The bulk of food waste arisings are generated by the Manufacturing⁵ sector (MFS), with a 39%, but also at Household⁶ level (HH), with a 42%. The value of the avoidable food waste has been established by applying the corresponding percentage from Monier et al. (2010) to the food purchases made by each sector. Concretely, the 6.3% of the food purchases made by WRS and FCS could be avoidable, whereas this figure increase to 15% at HH level. In the FCS, 4% to 10% of food purchases are estimated to become waste before reaching a customer and this waste is 90% avoidable, whereas no data is available from WRS. Due to that, the avoidable portion of food waste for those productive sectors has been calculated by multiplying the midpoint (7%) by the avoidable portion of waste, resulting in the 6.3% of the food purchases. In MFS, food waste is largely unavoidable, so this sector has not been considered in the simulation described just below. Finally, at HH level, food waste arisings represents 25% of food purchased (by weight), of which 60% could be avoidable; therefore the percentage of avoidable waste has been established in 15%.

Considering the previous information, five different scenarios has been set out in order to assess the economic impact of reducing avoidable food waste on the member states selected, (Germany, Poland and Spain):

² Monier et al. (2010) defines food waste as “waste composed of raw or cooked food materials and includes food materials discarded at any time between farm and fork” whereas, food waste at household level is considered as “waste generated before, during or after food preparation, such as vegetable peelings, meat trimmings, and spoiled or excess ingredients”. In both cases the food waste can be edible or inedible.

³ Production sector involving the distribution and sale of food products to individuals and organisations.

⁴ Production sector involved in the preparation of ready-to-eat food for sale to individuals and communities; includes catering and restauration activities in the hospitality industry, schools, hospitals and businesses.

⁵ Production sector involved in the processing and preparation of food products for distribution.

⁶ Sector involves food waste generated in the home by consumers in household units.

- Scenario 1: Impact on the member states economies analyzed as a result of reducing the avoidable food waste generated by WRS, FCS and HH.
- Scenario 2 and 3: Impact of reducing the avoidable food waste in WRS and FCS respectively in terms of total output, GDP and employment on the three European economies.
- Scenario 4: Impact resulting of the abatement of the avoidable portion of food which ends up as being discarded by households in terms of total output, GDP and employment on Spanish, German and Polish economies.
- Scenario 5: Total Impact of reducing avoidable food waste on agrifood accounts, that is, SAM accounts representing the value of the commodities from agricultural activities and food manufacturing industry, in terms of total output for Spain, Germany and Poland.

The following tables show the main results obtained for each one of the scenarios described, where “shock” is the total amount included within Z' vector. This means the monetary value of the avoidable portion of food waste calculated by applying the aforementioned percentage to the demand of agrifood sector commodities, made by the corresponding agents under each scenario. The economic impact derived from this negative shock is given in absolute terms and in percentage of change over the baseline data encompassed in the corresponding AgroSAM. Table 2 exhibits the results of reducing avoidable food waste by all the agents (Scenario 1). As can be seen, Polish economy exhibits the smallest size for the shock (€6,868 MM), whereas this shock is nearly double on Spanish economy (€12,742 MM) and more than four times on the German economy (€29,968 MM). However in relative terms, countries show a reverse order and the differences among them are not so pronounced. Thus, the effects on German economy are the smallest, with change on production and GDP of -1.42 % and -1.21% respectively. The impact on Spanish economy is slightly higher, with figures of -1.57% and -1.49 %, and greater on Polish economy, with a reduction of -2.32% in production and -2.15% in GDP. Employment does not follow the previous pattern since Spain and Poland exhibit lower and quite similar

figures in terms of labour shedding compared with Germany, nearly doubling the job lost due to reduce the production of the commodities demanded by WRS, FCS and HH.

(Table 2 about here)

Tables 3 and 4 show the shock due to avoiding food waste within WRS and FCS (Scenarios 2 and 3). For both sectors, the portion of avoidable food waste established was the same (6.3% of food purchases); but the monetary size of the shock is quite different for each sector, such as the shock is much smaller within WRS than within FCS. In the case of WRS (Table 3), Germany exhibits the smallest shock (€73 MM) and thus the impact in terms of production and GDP is barely -0.02%, whereas the reduction in labour reaches 6,400 employments. These figures are slightly higher for the Spanish economy, where the shock amounts for €108 MM, therefore the production and GDP decrease -0.07% and the labour falls in 11,378 employments. The Polish economy is the most affected by reducing the food waste within the WRS, the shock is €246 MM more than three times the size of the shock in Germany. The impact is also much higher compared to German economy since the production and GDP decreases -0.33% and the labour falls 36,580 employments, fifteen and six times the Germany figures.

(Table 3 about here)

As show in Table 4, the size of the shock due to reducing food waste by German and Spanish FCS is much greater than in the corresponding WRS. For those countries, the monetary value of the avoidable food waste is over one thousand millions of euros. Although the shock in German economy is greater in absolute terms (€1,602 M) compared to Spanish economy (€1,165 M), the effects on production and GDP are higher for the latter. The same does not apply for labour, for which labour decreases 75,989 employments in Germany compared to 54,616 in Spain. It is noteworthy that the smallest shock in Poland, almost nine time less than

in Germany, generates a similar impact in terms of production and GDP, but the impact is much less severe on the labour force, with a reduction of 29,915 employments.

(Table 4 about here)

The fourth scenario reflects the impact of reducing the avoidable food waste generated by HH. As pointed out by Monier et al. (2010), HH are responsible for the most part of waste arising as shown in Table 5. Germany exhibits the greatest shock (€28,293 M), Spain is in the midpoint (€11,468 M) and Poland the smallest one (€6,434 M). However, the effects in term of production and GDP are quite similar for the first two countries (between -1.3% and -1.5%), whereas they are slightly higher on Polish economy (around -2.5%). Turning attention to labour, the pattern again differs, that is, Germany exhibits the largest reduction of employment, followed at some distance by Poland and in lesser extent by Spain.

(Table 5 about here)

Finally, Table 6 show the impact of reducing avoidable food waste by all the agents on each agrifood account, in terms of production, since policies aiming at reducing the food waste are likely to be among important drivers of the changes in agrifood sector. Focusing on the greatest impact on each country, similar patterns can be detected, such as the most affected sectors are those producing cereals and meat. But also there are differences among countries highly related with the most consumed product of their national diet; so sectors producing milk and potatoes would have to be added to the list of most affected sector in the case of Germany; sectors related to fresh vegetables, processed sugar and oil plants production in the case of Spain; and processed sugar industry in the case of Poland.

Conclusions

The linear CGE model employed in this work allow us assessing the economic impact of reducing avoidable food waste arisings by differents agents, in terms of production, GDP and employment, rather than in input or output saving terms, as it made by the bulk of studies dealing with the economic impact of food wasted. The results indicate that the economic structure of the country, where reduction could be implemented, determines the impact of the measures. Thus, equal food waste redution by Wholesale/Retail sector or Food services/Catering has a similar impact in Poland, but that is not the case of Germany or Spain. The same happens when the reduction is aimed at household level. The differences in terms of economic structure but also in terms of most demanded agrifood products could explain these differences.

It also should be noted that AgroSAM database employed in this work provide a threefold advantage compared with the GTAP database used with other CGE models. First SAMs clearly reflect the linkages among sectors in the productive structure of each member state and their relation within the final demand, capturing the impact of reducing decision by the demand side on the whole economy. Second, the availability of highly dissagregated agrifood accounts, which provides a deeper insight of the most affected production activities. Third, the comparability of the results due to each course of action for the sample of member states chosen. The latter two points allows a better design of policies aiming at reducing food waste since global measures could be tailored according the characteristics of the economy for which such measure is intended.

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Table 1. Structure of an AgroSAM: Spain - 2007. Millions of euros.

| Receipts \Payments | Activities | Commodities | Labor | Capital | Government & ROW | Enterprises | Capital | WTRD & A_RTRD | Food servicies | Households | Total |
|---------------------------------|--------------------|--------------------|------------------|------------------|---------------------|------------------|------------------|------------------|-------------------|--------------------|--------------------|
| Activities | | 1,529,634.2 | | | 6,751.6 | | | | | | 1,536,385.8 |
| Commodities | 888,500.0 | | | | 652,953.1 | | 320,596.0 | 58,249.6 | 125,593.3 | 596,502.2 | 2,642,394.3 |
| Labor | 295,248.9 | | | | 811.2 | | | 49,605.5 | 175,968.4 | | 521,633.9 |
| Capital | 344,542.5 | | | | | | | 43,550.9 | 81,348.0 | | 469,441.4 |
| Government & ROW | 8,094.2 | 577,723.8 | 1,447.5 | 20,222.9 | 946,392.2 | 263,959.9 | 3,132.4 | 275.8 | 603.1 | 322,126.9 | 2,143,978.6 |
| Enterprises | | | | 224,095.7 | 182,501.3 | | | | | | 406,597.0 |
| Capital | | | | | 86,835.7 | 142,637.1 | 320,596.1 | | | 94,255.6 | 644,324.5 |
| WTRD & A_RTRD | | 151,681.8 | | | | | | | | | 151,681.8 |
| Food servicies | | 383,354.7 | | | 158.1 | | | | | | 383,512.9 |
| Households | | | 520,186.8 | 225,122.7 | 267,575.4 | | | | | | 1,012,885.0 |
| Total | 1,536,385.6 | 2,642,394.5 | 521,634.3 | 469,441.3 | 2,143,978.6 | 406,597.0 | 644,324.5 | 151,681.9 | 383,512.8 | 1,012,884.7 | 9,912,835.1 |

Source: Authors' elaboration.

Table 2. Scenario 1: Impact of reducing avoidable food waste by all the agents.

| | GERMANY | | SPAIN | | POLAND | |
|------------------------|-------------|-----------|-------------|-----------|-------------|-----------|
| Shock | -29,968 M€ | | -12,742 M€ | | -6,868 M€ | |
| | Impact | Variation | Impact | Variation | Impact | Variation |
| <i>Production (M€)</i> | -48,563.53 | -1.42 % | -24,145.97 | -1.57 % | -11,448.09 | -2.32 % |
| <i>GDP (M€)</i> | -18,134.76 | -1.21 % | -9,669.65 | -1.49 % | -4,185.58 | -2.15 % |
| <i>Employment</i> | -323,582.27 | | -162,323.37 | | -183,380.96 | |

Source: Authors' elaboration.

Table 3. Scenario 2: Impact of reducing avoidable food waste by WRS.

| | GERMANY | | SPAIN | | POLAND | |
|------------------------|-----------|-----------|------------|-----------|------------|-----------|
| Shock | -72.67 M€ | | -108.77 M€ | | -246.95 M€ | |
| | Impact | Variation | Impact | Variation | Impact | Variation |
| <i>Production (M€)</i> | -782.52 | -0.02 % | -1,260.62 | -0.07 % | -1,838.02 | -0.33 % |
| <i>GDP (M€)</i> | -370.05 | -0.02 % | -590.45 | -0.07 % | -772.62 | -0.32 % |
| <i>Employment</i> | -6,399.87 | | -11,378.29 | | -36,580.61 | |

Source: Authors' elaboration.

Table 4. Scenario 3: Impact of reducing avoidable food waste by FCS.

| | GERMANY | | SPAIN | | POLAND | |
|------------------------|------------|-----------|------------|-----------|------------|-----------|
| Shock | -1,602 M€ | | -1,165 M€ | | -187 M€ | |
| | Impact | Variation | Impact | Variation | Impact | Variation |
| <i>Production (M€)</i> | -10,450.98 | -0.28 | -6,934.86 | -0.41 | -1,684.07 | -0.30 |
| <i>GDP (M€)</i> | -4,613.71 | -0.27 | -2,994.03 | -0.40 | -690.20 | -0.30 |
| <i>Employment</i> | -75,989.38 | | -54,615.69 | | -29,915.10 | |

Source: Authors' elaboration.

Table 5. Scenario 4: Impact of reducing avoidable food waste by HH.

| | GERMANY | | SPAIN | | POLAND | |
|------------------------|-------------|-----------|-------------|-----------|-------------|-------------|
| Shock | -28,293 M€ | | -11,468 M€ | | -6,434 M€ | |
| | Impact | Variation | Impact | Variation | Impact | Variation |
| <i>Production (M€)</i> | -68,688.45 | -1.52 | -30,548.80 | -1.47 | -16,763.42 | -2.65 |
| <i>GDP (M€)</i> | -29,647.68 | -1.36 | -13,569.28 | -1.36 | -6,958.15 | -2.48 |
| <i>Employment</i> | -576,486.73 | | -259,869.57 | | -332,327.08 | -576,486.73 |

Source: Authors' elaboration.

Table 6. Scenario 5: Impact of reducing avoidable food waste on total production.

| AGRIFOOD ACCOUNTS | | GERMANY | | SPAIN | | POLAND | |
|-------------------|-----------------------------------|--------------|---------------|--------------|---------------|--------------|---------------|
| Code | Description | Impact (€MM) | Variation (%) | Impact (€MM) | Variation (%) | Impact (€MM) | Variation (%) |
| 1 A_OWHE | Other wheat | -326.47 | -7.60 | -148.64 | -10.60 | -223.61 | -11.78 |
| 2 A_DWHE | Durum wheat | -0.91 | -11.35 | -34.59 | -7.99 | 0.00 | - |
| 3 A_BARL | Barley | -119.29 | -5.71 | -193.83 | -6.67 | -78.92 | -9.45 |
| 4 A_MAIZ | Grain maize | -64.79 | -7.25 | -77.87 | -7.61 | -38.58 | -9.66 |
| 5 A_OCER | Other cereals | -81.20 | -7.29 | -29.08 | -7.47 | -219.81 | -8.92 |
| 6 A_PARI | Paddy rice | 0.00 | - | -19.36 | -7.30 | 0.00 | - |
| 7 A_RAPE | Rape seed | -91.97 | -4.68 | -0.67 | -6.00 | -28.39 | -3.75 |
| 8 A_SUNF | Sunflower seed | -1.21 | -5.36 | -24.95 | -6.97 | 0.00 | - |
| 9 A_SOYA | Soya seed | 0.00 | - | -0.02 | -6.82 | 0.00 | - |
| 10 A_OOIL | Other oil plants | -0.21 | -6.00 | 0.00 | -7.49 | -5.08 | -13.17 |
| 11 A_STPR | Other starch and protein plants | -3.46 | -6.37 | -3.60 | -5.59 | -15.19 | -13.14 |
| 12 A_POTA | Potatoes | -148.74 | -8.64 | -84.24 | -11.11 | -147.07 | -10.23 |
| 13 A_SUGB | Sugar beet | -34.20 | -4.13 | -13.51 | -6.23 | -38.03 | -7.52 |
| 14 A_FIBR | Fiber plants | 0.00 | - | -2.14 | -4.43 | -0.08 | -3.22 |
| 15 A_GRPS | Grapes | 0.00 | - | -81.81 | -10.60 | 0.00 | - |
| 16 A_FVEG | Fresh vegetables, fruit, and nuts | -432.47 | -12.34 | -1,201.14 | -7.93 | -374.30 | -12.43 |
| 17 A_LPLT | Live plants | -132.60 | -4.15 | -197.47 | -8.34 | -23.45 | -12.28 |
| 18 A_OTCR | Other crops | -14.93 | -2.23 | -61.75 | -4.92 | -14.52 | -8.74 |
| 19 A_FODD | Fodder crops | -618.71 | -10.26 | -69.22 | -7.60 | -131.69 | -9.12 |

| AGRIFOOD ACCOUNTS | | GERMANY | | SPAIN | | POLAND | |
|--------------------|--|-------------------|----------------|-------------------|---------------|------------------|----------------|
| 21 A_COMI/ SGMI | Raw milk from cattle, sheep and goats | -973.62 | -8.88 | -390.86 | -11.24 | -525.80 | -12.21 |
| 22 A_LCAT | Cattle, slaughtered | -244.50 | -5.86 | -271.86 | -8.60 | -81.39 | -6.20 |
| 23 A_PIGF | Swine, slaughtered | -450.31 | -7.42 | -533.90 | -9.12 | -402.73 | -11.59 |
| 24 A_LSGE | Sheep, goats, horses, asses, mules and hinnies, slaughtered | -21.06 | -6.10 | -183.12 | -10.59 | -3.37 | -2.82 |
| 25 A_EGGS | Eggs | -63.40 | -9.80 | -133.68 | -10.58 | -127.64 | -12.98 |
| 26 A_PLTR | Poultry, slaughtered | -127.28 | -7.07 | -242.72 | -10.41 | -238.15 | -10.68 |
| 28 A_OANM | Other animals, live, and their products | -15.21 | -4.66 | -1,7.59 | -5.06 | -5.04 | -8.01 |
| 37 A_RICE | Rice, milled or husked | -0.23 | -9.81 | -31.86 | -7.92 | 0.00 | |
| 38 A_OFOD | Other food products | -8,436.48 | -12.38 | -3,877.00 | -10.79 | -57.15 | -7.46 |
| 39 A_SUGA | Processed sugar | -184.62 | -5.30 | -90.91 | -8.03 | -196.05 | -9.68 |
| 40 A_VOIL | Vegetable oils and fats, crude and refined; oil - cake and other solid residues, of vegetable fats or oils | -140.10 | -4.51 | -280.56 | -7.02 | -46.55 | -4.99 |
| 41 A_DAIR | Dairy products | -3,197.29 | -10.22 | -1,448.88 | -13.01 | -2,073.73 | -12.56 |
| 42 A_BFVL | Meat of cattle, fresh, chilled or frozen | -428.59 | -8.58 | -399.74 | -10.71 | -97.21 | -7.40 |
| 43 A_PORK | Meat of swine, fresh, chilled or frozen | -740.91 | -9.16 | -680.23 | -10.75 | -476.05 | -12.26 |
| 44 A_SGMT | Meat of sheep, goats, and equines, fresh, chilled or frozen | -36.44 | -10.20 | -364.44 | -12.93 | -5.94 | -5.36 |
| 45 A_POUM | Meat and edible offal of poultry, fresh, chilled or frozen | -166.82 | -11.12 | -334.75 | -13.29 | -529.45 | -12.57 |
| 46 A_BEVR | Beverages | -1,903.46 | -12.25 | -796.94 | -7.38 | -23.18 | -5.94 |
| TOTAL | | -19,201.48 | -246.68 | -12,322.93 | -309.1 | -6,228.15 | -276.12 |