The Global Food System: A compositional-based model and a case study

García-Martín, Rosa[1] and E. Jarauta-Bragulat[2]

[1] Universidad Nacional de Educación a Distancia (UNED), Instituto de Salud Carlos III (ISCIII), Spain, Madrid; *rosagm92.rga@gmail.com*

[2] Universitat Politècnica de Catalunya (UPC) and UNESCO Chair *Science and Innovation for Sustainable Development: Global Food Production and Food Safety* (Triptolemos Foundation), Spain, Barcelona

Summary

Usually, the food system has been considered as what is known as the food chain, that is, production, distribution, and consumption. Clotet et al. (2010) transcend this approach and propose a new concept called Global Food System (GFS), in which four conceptual axes are considered: Availability (A), Economy (E), Politics (P) and Social environment (S). This new approach makes it possible to take into account different elements that intervene in the food system, which allows us to approach from a much more general and coherent perspective.

Axis A allows to study of all aspects related to agricultural, fishing and livestock production; in the second axis E, are considered those aspects related to the chain food production economy, considered from global and citizen perspectives; in the third axis P, the elements of production and safety policy are considered and finally in the fourth axis S all aspects related to knowledge, behavior and culture related to food are included.

The GFS approach is adequate from a conceptual point of view, but it must be equipped with a mathematical model to analyze aspects that can be expressed numerically and, therefore, be analyzed by applying mathematical and statistical methods. Given that it is a system articulated in four axes, the perspective offered by Compositional Data Analysis with its wealth of concepts, methods, and tools seems to be the appropriate instrument to address this mathematical model of GFS. This mathematical approach has been formulated by Clotet et al. (2013) and completed by Jarauta-Bragulat et al. (2018).

In this work, we present an application of the statistical-mathematical model for the quantitative analysis of the GFS and a new approach for its improvement and development is highlighted. Likewise, a case study focused on the analysis of the food systems of two groups of European countries is presented: the first group from Northern Europe (Denmark, Finland, and Sweden) and the second group from Mediterranean Europe (France, Italy, and Spain). The study makes it possible to highlight aspects of the food systems of both groups of countries and to draw useful conclusions at different levels.

Keywords: Global Food System, Health Psychology, Compositional Dynamic System, Compositional Differential Linear Model.

1 Introduction

A good, healthy, and balanced diet generally means a direct relationship with good health. Food understood as a food diet is part of a more complete system: the food system. In this system, elements of

availability, economy, public policies, and food knowledge, behaviour and culture intervene. It is important to have tools to globally characterize the food system of a social environment, be it a region, a country, or a group of countries. Clotet et al. (2010, 2013) formulate a conceptual model of the global food system that allows an adequate characterization of the food reality of a society and the implications that this has on public health.

The behaviour, attitude, and processes that occur in people and how they affect the perception that these people have about their state of health, are part of a field of knowledge known as health psychology. The concept of health, as it is currently understood, has a multidimensional meaning since it refers not only to the absence of diseases, but also to the self-perception of well-being, both physically and psychologically (Blázquez-Abellán et al., 2016). And in addition, the concept of health extends to the environment, that is, to what refers to feelings and daily experiences, which, if balanced, motivates the person in their social integration and that is also considered an important part of the meaning underlying the term health.

In this sense, it should be noted that there are two clearly different aspects: on the one hand, health is considered objectively, measured with physical, chemical, and biological indicators (medicine) and on the other, individual self-perception in relation to one's own health (psychology of health). In the latter case, the influence of mood, one's own opinions about health and quality of life, including one's ability to cope with adverse situations, notably influences the psychological perception of a person's health (Díaz-Menéndez et al., 2008). The state of mind and other psychological elements are positively influenced by the practice of healthy lifestyle habits, among which we must highlight a correct, healthy, and balanced diet. Self-perceived health is a measure influenced and determined by multiple factors; of particular interest is the relationship between self-perception of good health and lifestyles, especially eating habits, which have a very significant influence on the feeling of personal well-being and on the psychological perception of one's own health.

Thus, deepening our knowledge of the food system is essential to contribute from dietary health to a good psychological perception of our own general health. Therefore, in this work two basic objectives are proposed: (1) presenting a description of the conceptual and mathematical model of the Global Food System (Clotet et al., 2013); (2) applying the mathematical model based on Compositional Data Analysis methods and tools associated with the Global Food System (Jarauta-Bragulat et al., 2018) to the study of the food systems of two sets of countries: Spain, France, Italy (Mediterranean) and Denmark, Finland, Sweden (Nordic), as a comparison of two best known healthy diets, the Mediterranean and the Nordic, respectively.

2 Model, methodology and variables

2.1 The Global Food System conceptual model

The conceptual model of the *Global Food System* (GFS) was formulated by Clotet et al. (2010, 2013) and completed with an analytical model and an application in Jarauta-Bragulat et al. (2018). In the conceptual model of GFS, four axes are considered: food availability (A), food economy (E), public policies in the food system (P) and social environment (S), which includes aspects such as knowledge, attitude, behavior and culture. The conceptual model is completed with a quantitative model based on Compositional Data Analysis (Aitchison, 1986; Pawlowsky et al. 2015), which allows quantitative information of data related to variables of each of the axes to be analyzed and comparative results of variables to be obtained. The model allows comparative analysis between food systems of different countries and territories, based on the defined variables and time series of data on these variables.

2.2 Applying the GFS analytical model

The procedure for applying the quantitative model associated with the GFS is as follows:

1. A database must be available for each variable, with the total values for each year of the series.
2. The relative values per inhabitant and year of each variable are calculated (population data must be available for the same years as the data series).
3. The proportions or relative values of each country in relation to the whole are calculated for each variable, obtaining the time series of proportions for each country.
4. To quantify the relative position of each country in relation to the group, represented by its geometric mean, the logarithm of the quotient between the proportion of each country and the geometric mean of the proportions of the series is calculated. The value obtained is called *position ratio* and is also expressed by means of a time series.
5. The compositional data adjustment model (Egozcue and Jarauta-Bragulat, 2014) is applied through compositional linear differential equations. The future estimate or prospective is applied to a period of years equal to one third of the years of the data series used.
6. For each variable, a table is created that reflects the values of the position ratio at the initial moment of the data series, at the final moment of the data series and at the final year of the forecast calculated according to the model.
7. The average values of the position ratios are calculated for each year and for each variable. The average values of the set in the initial, final, and estimated years are called the Sectoral Triptolemos Indexes and their average is called the General Triptolemos Index. The positive sign of a sector index means a relative position above the average of the group and the opposite if it is negative.

2.3 Selected variables

The following variables have been selected for each axis of the GFS conceptual model:

- **Axis A, Food availability**. Variables: (A1) Livestock Availability, (A2) Agricultural Availability, (A3) Fishery Availability, (A4) Available Food Energy and (A5) Available solar energy for agricultural production.
- **Axis E, General and food economics**. Variables: (E1) Gross domestic product (GDP) per capita, (E2) Gross national income (GNI) per capita, (E3) Household final consumption expenditure by the purpose of consumption of food and non-alcoholic beverages, (E4) Gross capital in sectoral RD per capita (% of GDP) and (E5) Presence in GDP of the Agriculture, forestry and fishing sectors.
- **Axis P, General policy and agri-food policy**. Variables: (P1) Government spending policy on Agriculture, Forestry and Fishing, (P2) Agricultural production policy on the surface, (P3) Social protection policy, (P4) Investment policy on Agriculture, Forestry and Fishing and (P5) Financing of the Common Agricultural Policy, CAP.

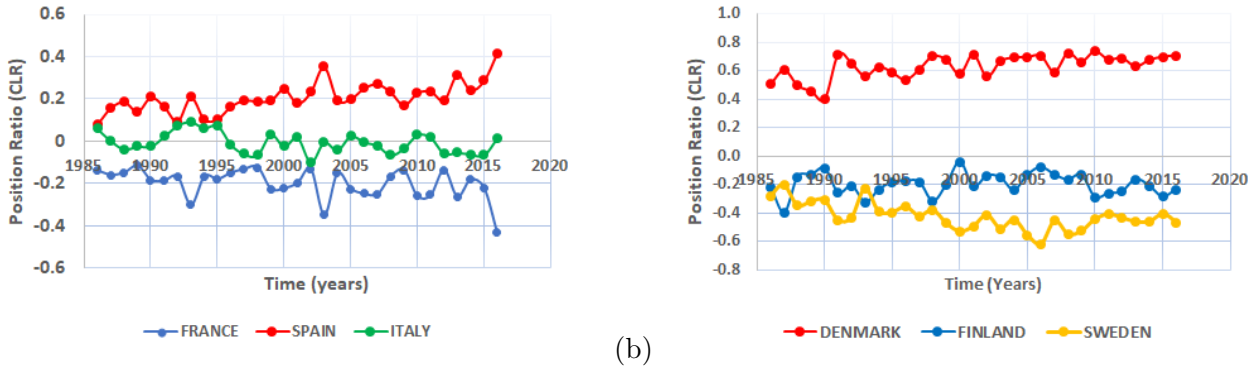
- **Axis S, Social environment (Food Knowledge, Behavior and Culture)**. Variables: (S1) Scientific publications in food sciences, (S2) Scientific publications in agricultural and biological sciences, (S3) Consumption of alcohol or alcoholic beverages, (S4) Mean total cholesterol and (S5) Mean Body Mass Index.

All data sets have been downloaded from public webpages (Faostat, Eurostat, World Bank and others); time data series are from 11 to 30 years, to ensure adequate statistical significance.

3 Results

3.1 Global Food System variables

For each group of countries, each of the 20 variables of the Global Food System is studied and the position ratios for each of them are obtained. For example, Figure 1 shows the graphs of the position ratios for variable A2 (agricultural availability).



(a) (b)

Figure 1. Time series of position ratio for agricultural availability per capita: (a) Mediterranean countries; (b) Nordic countries

3.2 Global Food System time evolution in countries

The linear compositional differential model formulated by Egozcue and Jarauta-Bragulat (2014) is applied to the data series of proportions of each variable in the context of the countries of its own group, to obtain an estimate of these proportions in the future. The final year of the estimate is considered to be the final year of the data series plus 1/3 of the number of years of the data series. With this, we have three proportions for each variable: the initial one corresponding to the first year of the data series, the final one corresponding to the last year of the data series and the one corresponding to the last year of the estimation series. This makes it possible to prepare for each country an illustrative graph of its relative position in each variable and in each of the three situations described. Figure 2 shows these graphs in the cases of France and Denmark.

Figure 2. The position ratio (CLR) of the country in the three specific moments of characterization (first year of data, final year of data, final year of predicted values) for each selected variable: (a) France; (b) Denmark.

3.3 The Triptolemos Index diagram

To illustrate the position of each country in its own group, a graph of the sectoral Triptolemos Index for each country and for each variable is useful. This makes clear in each case the position of each of the countries in the group, as it can be seen in Figure 3.

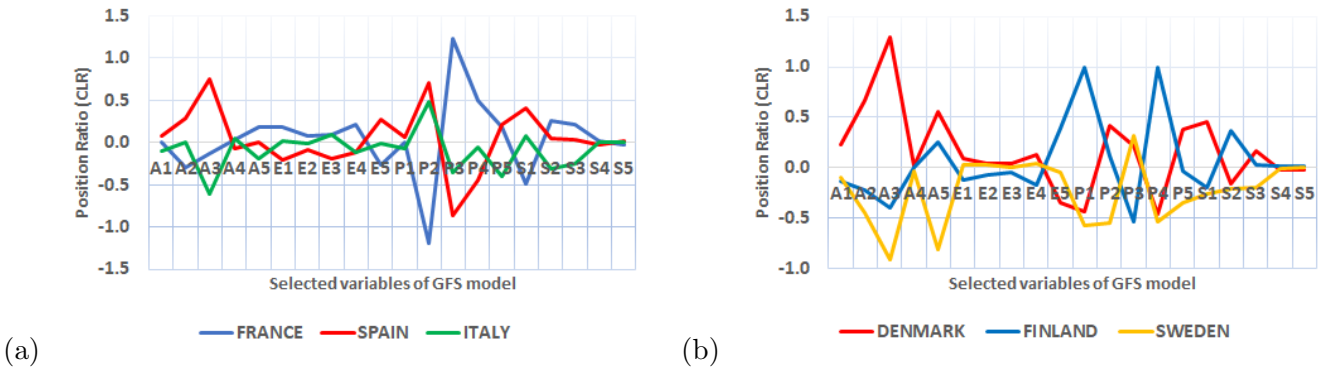


Figure 3. Sectoral Triptolemos Index for each country within its group: (a) Mediterranean countries; (b) Nordic countries.

Conclusions

- The conceptual model of the Global Food System (GFS) formulated by Clotet et al. (2010, 2013) has been revealed as a useful and adequate tool for characterizing and analyzing the food system of a country or a group of countries since it incorporates a more complete perspective for this analysis. Additionally, this conceptual model allows comparing the own perception of health related to food (axis S, social environment) with the factors related to objective aspects of the food system.

- The results of the application of the Compositional Data Analysis based model of GFS to the two groups of three Mediterranean countries and three Nordic countries, allow for analyzing the evolution of the respective indicators, comparing each one of the variables and formulating conclusions to be able to improve the alimentary health of the citizens of both country groups.
- In the Mediterranean countries, Spain obtains the best value of the Triptolemos Index (0.0438) with 40% of negative values in the position ratios; the second country is France with an index of 0.0418 and 35% of negative values in the position ratios and at third place Italy with an index of -0.0904 and 60% of negative values in the position ratios.
- In the Nordic countries, Denmark obtains the best value of the Triptolemos Index (0.1641) with 30% of negative values in the position ratios; the second country is Finland with an index of 0.0637 and 50% of negative values in the position ratios and at third place Sweden with an index of -0.2399 and 70% of negative values in the position ratios.

Acknowledgments

This work has been partially funded by the Spanish Ministry of Science, Innovation and Universities, project RTI2018-095518-B-C22 (MCIU/AEI/FEDER)

References

Aitchison J. (1986). *The statistical analysis of compositional data.* Monographs on statistics and applied probability. Chapman & Hall Ltd., London. Chichester: Wiley.

Blázquez-Abellán, G. et al. (2016). *Alimentación saludable y autopercepción de salud.* Atención Primaria; 48(8); 535-542. Elsevier.

Clotet, R.; Colomer, Y. and Mayor, F. (2010). *Human development and food: a global vision.* Global Food Security: Ethical and legal changes (ed. By C.M. Romeo-L. Escajedo and A. Emaldi). Wageningen Academic Publishers. The Netherlands.

Clotet, R.; Colomer, Y.; Jarauta-Bragulat, E., Mayor, F. (2013). *El sistema alimentario global: I - Definición de un espacio.* Revista Española de Estudios Agrosociales y Pesqueros, n.235, pp 13-32.

Díaz-Menéndez, C. and Gómez-Benito, C. coords. (2008). *Alimentación, consumo y salud.* Colección Estudios Sociales, n.24, 287 pp. Fundación "la Caixa".

Egozcue J.J., E. Jarauta-Bragulat (2014). *Differential models for evolutionary compositions.* Mathematical Geosciences 46(4):795–828.

Jarauta-Bragulat, E.; Colomer, Y.; Clotet, R (2018). *El sistema alimentario global: II - Aproximación cuantitativa al espacio agroalimentario de la Europa mediterránea.* Revista Española de Estudios Agro sociales y Pesqueros, n.249, pp. 15-38.

Pawlowsky-Glahn V., J.J. Egozcue, R. Tolosana-Delgado (2015). *Modeling and analysis of Compositional Data.* Wiley.