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Depetris-Chuavin et al. present a review of the costs and benefits of specific sustainability-oriented innovations, not only economic but also social and environmental in the Mediterranean region. To achieve this goal, the paper classifies the elements being reviewed according to the nature of the innovation and stages of the product life cycle it covers.

The extent to which the use of the Internet and web technologies can enhance consumer power and psychological empowerment is analysed by *Belharar and Chakor* in Morocco. The results show a positive and direct effect between the use of the Internet and web technologies and the power of consumers in terms of food, and consequently their psychological empowerment in their food decision-making.

Galera-Quiles et al. analyse the factors that can influence strategic decision-making in export performances in Spanish agrifood. The results show that the age of the management is a key factor in being more export-oriented, as are the control of inputs through information and communication technologies, the implementation of environmental innovations, and partnerships with universities and research centres.

Şengül and Saner determine the sustainability level of beekeeping farms in the Aegean region of Turkey. The results showed that the economic sustainability index of beekeeping farms was 0.45, social sustainability was 0.36, environmental sustainability was 0.92, and the overall sustainability was 0.58. The results showed that transregional migratory beekeeping harmed sustainable beekeeping due to its negative effect on both bee welfare and cost increase.

González-Azcárate et al. analyse the potential opportunities and challenges of Civic crowdfunding (CiC) with matchfunding (MF) as a policy tool for local governments to finance place based food initiatives and promote sustainable local food systems. The results highlight the potential of CiC / MF to help local food project promoters to raise financial resources, as well as learn marketing skills and build a social support base around their projects.

Resano Ezcaray et al. focus on an array of meat attributes and their role in consumers' preferences, from both consumers' own perspective and the opinions of other value chain agents in Spain. Results reveal the existence of a niche market for more differentiated beef, where health qualities and local origin are particularly appealing. The authors found a certain degree of divergence between the agents' valuations, being wider with those placed farther from the consumer, as is the cattle farmer.

Öztornaci and Şengül aim to measure the impact of social support expenditures on poverty in Turkey. The study finds that multidimensional poverty values are approximately 2.5 times higher than one-dimensional values. Government spending was found to have no impact on multidimensional poverty, while private expenditure had a relatively minor impact.

Forecasting the dynamics of farm income: The case of the olive sector in Spain

José A. Gómez-Limón*, Sandra M. Sánchez-Cañizares**

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Abstract

The objectives of this paper are to determine the factors that influence interannual movements of farms between income categories, and to forecast future income categories of farms under several different market, climate, and policy scenarios. To achieve these goals, a methodology combining the Markov chain model with a partial proportional odds model is proposed. Spanish olive farms are taken as an illustrative case study. The results show that the income dynamics of these farms are mainly influenced by off-farm uncontrollable factors such as the output prices, the weather conditions, and the policy support. Moreover, farm-, farmer-, and management-specific factors also play a relevant role.

Keywords*: Farm viability, Farm accountancy data network, Markov chain model, Partial proportional odds model, Scenario analysis.*

1. Introduction

Low income is the main factor driving farm abandonment (van der Zanden *et al.*, 2017). For this reason, ensuring farmers receive a 'fair' income has been an objective of the European Common Agricultural Policy (CAP) since its origins in 1957, as a way to maintain productive activity and guarantee food supply for the population, as well as to support the vitality of rural areas and encourage the provision of multiple ecosystem services (Finger and El Benni, 2021). In fact, "support viable farm income and resilience of the agricultural sector across the Union to enhance long-term food security and agricultural diversity" is the first of the nine specific objectives set out to guide the design and implementation of the CAP during the next programming period 2022-2027 (EC, 2018).

Despite this stated objective of the CAP, the European Union (EU) has never established any norms on what should be understood by a 'fair' or 'viable' income (Hill and Bradley, 2015). This lack of specificity means there is no normative reference level with which to compare the income actually obtained by European farms. To fill this gap, scholars have studied farm income in an attempt to establish different reference levels based on objective criteria, applying different analytical methodologies (e.g., Vrolijk *et al.*, 2010; Barnes *et al.*, 2020).

The study of farm income is a recurrent research topic within the agricultural economics

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literature, especially when periods of difficulty are detected in certain farming subsectors. This is the case with the olive sector in Spain, which recently experienced an acute market crisis caused by a cycle of low olive oil prices (2018-2020), negatively impacting farm income (MAPA, 2021). This situation sparked large protests by olive growers throughout 2019 and 2020, leading to an intense social and political debate in production regions about the current role and prospects for olive farming. The high volatility of farm income experienced by the olive sector justifies both its use as an illustrative case study and the interest in analysing farm income from a dynamic point of view, assessing the factors explaining interannual changes in farm income.

Within this framework, the objective of this paper is threefold. First, to analyse how olive farm income has evolved during the period 2009-2018, using accounting data from a representative sample of Spanish olive farms to assess the share of these farms that achieve an adequate income level, thus ensuring their viability in the medium-to-long term. Second, to determine the structural and socio-economic factors explaining the heterogeneity in income dynamics of these farms. And third, to estimate the effects of several feasible market (changes in olive oil prices), production (reduction in olive yields because of climate change), and policy (reductions in the CAP support) scenarios on their income.

To achieve the abovementioned objectives, a farm typology is proposed based on different farm income levels. Considering the farm-level accounting information provided by the Spanish Farm Accountancy Data Network, every farm sampled has been classified into an income category for each year in the analysed period, allowing the modelisation of the dynamics of farm income, observing how individual farms move between categories across the years. For this purpose, the Markov chain model is used. This methodological approach has already been used in the agricultural economics literature, especially in studies focused on farm structural change (e.g., Rahelizatovo and Gillespie, 1999; Zimmermann and Heckelei, 2012). However, it has seldom been used to analyse the dynamics of farm income (Phimister *et al.*, 2004; Barnes *et al.*, 2015). In fact, this paper adds to the existing literature by combining the Markov chain model with an ordinal regression (partial proportional odds) model for ex-ante policy assessment of future market, production, and policy scenarios. Moreover, this methodological contribution is of interest because the method can be easily replicated using the same data source in any other farming sector and member state within the EU, allowing useful comparative studies to be carried out (e.g., comparison of the dynamics of farm income across olive farms in Spain, Italy, and Greece).

2. Measuring farm income: a typology

2.1. *Data*

The analysis of farm income necessarily relies on microeconomic data at the farm level, adequately reflecting the heterogeneity of these production units in terms of their capacity to generate revenue and remunerate the inputs employed. In this sense, the information provided by the Farm Accountancy Data Network (FADN) is the best available option in EU countries. For the case of Spain, these data are provided by the Spanish Farm Accountancy Data Network (*Red Contable Agraria Nacional*, RECAN), the Spanish branch of the FADN.

The RECAN annually collects structural, productive, economic, and financial information on a representative sample of Spanish commercial farms. Among the main advantages of using this data source are:

1. The sampling of farms is carried out by quotas according to the EU's farm typology (Regulation (EC) 1242/2008), considering the strata established by: a) economic dimension, quantified in terms of total standard gross margin (SGM) expressed in Euros; b) type of farming (TF); and c) Spanish Autonomous Communities.
2. The sample size of the RECAN annually exceeds 8,700 farms. This large size and the quota sampling procedure guarantee that the sample collected by the accounting

network is representative of the population of commercial farms in Spain.

3. The RECAN data gathering is carried out using the methodology applied throughout the EU (Regulation (EC) 1217/2009), thus contributing to a harmonised source of microeconomic data on farms at the European level. Therefore, the income indicators proposed for this work for Spanish olive farms could be replicated for other EU countries and other types of farming, enabling comparative analyses.

For all these reasons, the RECAN is a suitable database for the proposed analysis of the income dynamics of Spanish olive farms, allowing a reliable approximation of the heterogeneity in this agricultural sector.

The only limitation of the RECAN worth mentioning is that the population of farms analysed is not the whole population of Spanish farms (945,024 according to the latest official figures). As with all the other national FADN branches, the population considered by the RECAN consists only of "commercial" farms; that is, those with an annual SGM greater than 8,000 Euros (about 430,000 farms in Spain). Nevertheless, it should be pointed out that the sample collected annually by the RECAN represents a population of farms that manages 89% of the farmland in Spain (20.6 million hectares) and produces 96% of agricultural output at the national level. For this reason, the data and results obtained using this source are useful for policy analysis.

The analysis carried out was based on the microdata of the farms classified as the type TF 37 (specialised olive farms) included in the RECAN samples from 2009 to 2018. The size of the annual subsamples of farms belonging to the TF 37 has ranged throughout the period analysed between 224 (in 2009) and 363 (in 2018), with information available for a total of 3,156 observations (i.e., total number of farms for the full ten years).

2.2. *Farm income typology*

Many authors (e.g., Vrolijk *et al.*, 2010; Barnes *et al.*, 2020) propose assessing farm viability by taking several different income levels as references or benchmarks. In this paper, we follow this approach considering two references to measure the viability of olive farms in Spain. These two benchmarks are presented below, along with the viability indicators derived from them, which then allow us to classify the analysed farms according to their level of income.

The first income reference to be considered is the *total opportunity costs* incurred by the farmer because of the use of all internal resources (i.e., factors of production owned by the farmer) in his/her farming activities (O'Donoghue *et al.*, 2016; Coppola *et al.*, 2020). In the case where the farm income is enough to remunerate (i.e., higher than) all the opportunity costs for the use of the labour, capital, and land factors provided by the farmer, it can be said that factor allocation is economically efficient, making the farming activity viable in the long term. This income level would allow the generation of an economic surplus that can be reinvested in the farm, not only ensuring its economic sustainability but even enabling its growth.

To operationalise this first reference, a first viability indicator ($VI1$) is proposed as the ratio between the Farm Net Income (FNI) and the sum of the estimated values of the farmer's opportunity costs (labour, land, and capital):

$$VI1 = \frac{FNI}{OC_{labor} + OC_{land} + OC_{capital}} \quad (1)$$

The opportunity costs are estimated by calculating the potential remuneration that could be obtained if the factors of production provided by the farmer were used in the best possible alternative:

a) *Opportunity costs of labour* (OC_{labor}). For this case study, we valued this cost considering the average wage in the Spanish economy as the reference (EC, 2018). Thus, OC_{labor} was obtained at the farm level by multiplying this average wage by the agricultural work units provided by the farmer and his/her family.
b) *Opportunity costs of owned land* (OC_{land}). It is assumed that the best alternative use for owned land factor is renting it out (Coppola *et al.*, 2020). Thus, this opportunity cost was calculated by multiplying the number of hectares of owned farmland by the average

rental price paid by farmers in the TF 37 (olive farming), with the latter data also being obtained from the RECAN microdata set.

c) *Opportunity costs of owned capital* (other than owned farmland) ($OC_{capital}$). Similar to previous studies (e.g., Vrolijk *et al.*, 2010; Coppola *et al.*, 2020), this opportunity cost was calculated on the basis of the interest paid for long-term public debt. Thus, $OC_{capital}$ was obtained by calculating the value of the farm equity less the value of owned land multiplied by the tax-free yield of 10-year government bonds.

The second income reference considered to assess the degree of viability of farms is the opportunity cost of the labour provided by farmers (Argilés, 2001; EC, 2018). Considering OC_{labor} as a reference for the farm income, the second of the viability indicators ($VI2$) is defined as follows:

$$VI2 = \frac{FNI}{OC_{labor}} \quad (2)$$

If the income of a farm is higher than this benchmark, it can be affirmed that this farm is viable in the short term, insofar as this income is a suitable remuneration for the labour provided by the farmer, allowing him/her to have a fair livelihood, similar to other people working in other economic sectors. Conversely, those farms with an income below the opportunity cost of labour can be considered as non-viable since farming is achieved at the cost of undervaluing the labour provided by the farmer. Indeed, under these circumstances, the farm is economically unsustainable in the long run, and the continuity of production is only explained by the farmer's lack of labour opportunities.

Taking into account the two abovementioned viability indicators, olive farms can be classified into three categories. Those farms with $VI2$ values lower than or equal to one are considered "*non-viable*" (category 1 −*C1*− of the viability scale). Those farms with $VI2$ values higher than one, but with $VI1$ values lower than one are considered "*viable in the short term*" (category 2 −*C2*−of the viability scale). Finally, those farms with a value of $VI1$ greater than or equal to one can be qualified as "*viable in the long term*" (category 3 −*C3*− of the viability scale).

3. Methodological approach for analysing the dynamics of farm income

3.1. *Markov chain approach*

Zimmermann *et al.* (2009) provide a literature review of relevant methods for forecasting change in the distribution of farm characteristics (i.e., number of farms in classes or categories defined by a typology). These authors conclude that the Markov chain model (MCM) is the most suitable approach to analyse the dynamics of farm changes (i.e., movements of farms between categories).

An MCM focused on the dynamics of farms is based on three basic elements (Rahelizatovo and Gillespie, 1999): a) a farm typology considering a finite set of C farm categories; b) the initial distribution of farms according to this typology, described by the matrix X^0 $(1\times C)$, where x_i^0 represents the number (or share) of farms in the category i in the first period analysed (t=0); and c) the stochastic transition probability matrixes (TPM) P^t $(C\times C)$ showing the probabilities of moving between farm categories during the T periods considered (t=1,...T).

When the TPM does not change over time, it is said the MCM is stationary. However, this is not generally the case for economic phenomena such as farm income, which is affected by multiple exogenous variables (e.g., product prices, input costs, production technology, public support, legal requirements, etc.). Since changes in these exogenous variables impact farm viability, transition probabilities are time-varying, leading to a non-stationary MCM (i.e., different TPMs for each period t). Accounting for non-stationarity, any change process considering an initial farm distribution X^0 and the TPMs P^t can be represented as follows:

$$X^0_{(1\times C)} \times P^1_{(C\times C)} \times P^2_{(C\times C)} \times \ldots \times P^T_{(C\times C)} = X^T_{(1\times C)} \quad (3)$$

where the matrix X^T $(1\times C)$ presents the farm distribution in period T. Thus, this general expression can be used to forecast the future distribution of farms among the C categories considered when the matrixes P^t structure is known.

Each element p_{ij}^t of the TPM P^t represents the probability of a single farm classified in category i in period t–1 being classified in catego-

ry j in period t. These transition probabilities also have the following two characteristics: a) $0 \leq p_{ij}^t \leq 1$ for every category i and j, and every period t, and b) $\sum_{j=1}^{C} p_{ij}^t = 1$ for every category i and period t.

It is usually assumed that the movement of farms from one farm category to another follows a first-order Markov chain; this is, that the probability of the movement of a farm in period t-1 to another farm type in period t is independent of movement in earlier periods. In these cases, the number of farms in category j in period t (n_j^t) depends on the number of farms in all farm categories i in the preceding period (t-1) multiplied by their respective transition probabilities p_{ij}^t:

$$n_j^t = \sum_{i=1}^{C} n_{ij}^{t-1} \times p_{ij}^t \quad (4)$$

If microdata are available to account for single farm movements between categories for each period, transition probabilities p_{ij}^t can be estimated as follows:

$$\hat{p}_{ij}^t = \frac{m_{ij}^t}{\sum_{j=1}^{C} m_{ij}^t} \quad (5)$$

where m_{ij}^t is the number of farms in category i in period t-1 that moved to category j in period t.

Note that transition probabilities obtained using Equation (5) based on observed data are just estimated values of real unknown parameters (p_{ij}^t). However, the values recovered by the use of the microdata are proven to be the maximum likelihood estimators of real transition probabilities (Gourieroux, 2012), allowing their use as unbiased values of these parameters for empirical applications.

Moreover, transition probabilities explaining the dynamics of farms' characteristics are functions of a full array of exogenous factors. Most of these factors are time-varying, justifying the non-stationary MCM. For this reason, an econometric model estimating the effect of these independent variables on transition probabilities is also required:

$$\hat{p}_{ij}^t = f_{ij}(Z^t, \beta_{ij}) \quad (6)$$

where f_{ij} is the function of the vector of explanatory variables Z^t and the matrix of parameters β_{ij} which relates to the independent variables considered.

Based on this theoretical framework, we implement a two-step approach: the first step involves calculating the non-stationary transition probabilities using Equation (5), and the second step estimating the influence of the exogenous variables on these probabilities using Equation (6).

3.2. *Factors determining the dynamics of farm income*

Coppola *et al.* (2020) and Barnes *et al.* (2020) have recently reviewed the factors affecting the income levels and viability of EU farms. They highlight the influence of the farmer's socio-demographic characteristics, the farm's structural characteristics, and the farmer's productive choices. Moreover, it is also worth pointing out the role of off-farm uncontrollable factors in farms' income dynamics, notably those related to the volatility of agricultural markets and changing weather conditions (e.g., Poon and Weersink, 2011) and those linked to shifting agricultural policy instruments (e.g., Biagini *et al.*, 2020; Cardone *et al.*, 2021). Taking into account this evidence and the information available for the empirical analysis, four kinds of factors were considered as explanatory variables that may potentially shape the functions f_{ij} (i.e., influence the dynamics of olive farm income):

1. *Farmer's socio-demographic characteristics*: age (*AGE*), agricultural training (*AGTRAIN*), family labour (*FAMLAB*), and land ownership (*LANDOWN*).
2. *Farm's structural characteristics* (economies of scale, agronomic suitability): farm size (*FSIZE*), agronomic suitability for olive production (*AGSUIT*), and olive area under irrigation (*IRRIG*).
3. *Farmer's productive choices* (production technology and financial situation): specialisation in olive production (*SPEC*), intermediate consumption intensity (*ICINT*), capital intensity (*CAPINT*), outsourcing (*OUTSOUR*), and debt-equity ratio (*DEBEQRAT*).
4. *Off-farm uncontrollable factors* (market, climatic, and policy conditions): a) bulk olive oil price (*OPRICE*), b) annual weather con-

ditions accounting for precipitation and temperature differences impacting olive yields (*WEATHER*), c) CAP decoupled payments (*CAPDP*), and d) interest rate (*IRATE*).

Table 1 shows the details about how these variables are operationally defined, the units of measurement, and the sources of the data. Table 2 shows the descriptive statistics of the explanatory variables included in the analysis.

The regression models estimated (see next section) do not include the variables *IRATE* (interest rate) and *IRRIG* (olive area under irrigation) because of multicollinearity problems. Specifically, *IRATE* presented a high correlation with *OPRICE*, while *IRRIG* was collinear with *AGSUIT* and *ICINT*. Although several alternative regression models were proposed to overcome the multicollinearity problems, we opted for those that elim-

Table 1 - Potential explanatory variables of the dynamics of olive farm income.

Theoretical concept	*Variable*	*Acronym*	*Type of variable*	*Measurement*	*Units*	*Source*
Farmer's socio-demographic characteristics	Age	AGE	Farm	Age	Years	RECAN
	Agricultural training	AGTRAIN	Farm	Dummy variable: only practical experience (0); agricultural degree (1)	---	RECAN
	Family labour	FAMLAB	Farm	Family labour as a percentage of total farm labour	Percentage	RECAN
	Land ownership	LANDOWN	Farm	Owned land as a percentage of total farmland	Percentage	RECAN
Farm's structural characteristics	Farm size	FSIZE	Farm	Farm size	Hectares	RECAN
	Agronomic suitability for olive production	AGSUIT	Farm	Average olive yield 2009-2018 as a time-invariant factor measuring land productivity	kg olive oil/ hectare	RECAN
	Olive area under irrigation	IRRIG	Farm	Irrigated olive area as a percentage of the total olive area	Percentage	RECAN
Farmer's productive choices	Specialization in olive production	SPEC	Farm	Olive area as a percentage of total farmland	Percentage	RECAN
	Intermediate consumption intensity	ICINT	Farm	Value of intermediate consumption (fertilizers, phytosanitary products, fuel, etc.) per hectare	€/hectare	RECAN
	Capital intensity	CAPINT	Farm	Non-land assets per hectare	€/hectare	RECAN
	Outsourcing	OUTSOUR	Farm	Agricultural practices subcontracted over total costs	Percentage	RECAN
	Debt-equity ratio	DEBEQRAT	Farm	Total debt over equity	Percentage	RECAN
Off-farm uncontrollable factors (climatic, market, and policy conditions)	Bulk olive oil price	OPRICE	National	Olive oil price index based on the average bulk olive oil price in Spain 2009-2018=100%	Percentage	Spanish Ministry of Agriculture (MAPA)
	Annual weather conditions	WEATHER	Province	Province yield index based on the average yield for rain-fed olive 2009-2018=100%	Percentage	Spanish Ministry of Agriculture (MAPA)
	CAP decoupled payments	CAPDP	Farm	CAP decoupled payments per hectare	€/hectare	RECAN
	Interest rate	IRATE	National	Spanish Government 10Y Bond yield	Percentage	Spanish Ministry of Finance

Note: Monetary variables were deflated using the Spanish Consumer Price Index (CPI) (Instituto Nacional de Estadística, INE, www.ine.es).

Table 2 - Descriptive statistics of explanatory variables of the dynamics of olive farm income.

Variable	*Acronym*	*Average*	*St. Dev.*	*Skewness*	*Kurtosis*
Age	AGE	58.38	10.91	0.103	0.430
Agricultural training	AGTRAIN	0.11	0.32	2.462	4.064
Family labour	FAMLAB	62.40%	25.56%	-0.305	-0.604
Land ownership	LANDOWN	87.08%	28.24%	-2.220	3.652
Farm size	FSIZE	39.50	59.44	6.723	64.007
Agronomic suitability for olive production	AGSUIT	668.09	384.66	1.894	12.043
Olive area under irrigation	IRRIG	28.75%	41.61%	0.939	-0.941
Specialization in olive production	SPEC	93.25%	14.56%	-2.386	5.317
Intermediate consumption intensity	ICINT	584.21	410.13	1.452	2.649
Capital intensity	CAPINT	3,998.92	5,322.31	9.713	134.594
Outsourcing	OUTSOUR	4.65%	9.53%	2.660	7.755
Debt-equity ratio	DEBEQRAT	1.47%	24.43%	34.638	1,410.547
Bulk olive oil price	OPRICE	105.93%	24.25%	0.169	-1.189
Annual weather conditions	WEATHER	102.20%	36.66%	0.362	1.695
CAP decoupled payments	CAPDP	544.93	433.34	1.630	5.075
Interest rate	IRATE	4.14%	0.54%	-0.369	-1.394

Note: The descriptive statistics reported have been calculated using the 3,156 observations gathered by the RECAN subsamples for the TF 37 (specialized olive farms) from 2009 to 2018. However, it is worth noting that the subsample size for this type of farming has not remained constant throughout the period analysed; it has gradually increased from 224 farms in the year 2009 to 363 farms in the year 2018. This explains why the averages of the variables WEATHER or OPRICE are not equal to 100% as might be expected. In these cases, mean values slightly higher than 100% actually indicate that olive yields and prices for olive oil were higher during the last years considered (those with larger sample size) than over the first years analysed (those with smaller sample size).

inate *IRATE* and *IRRIG* since they had the best goodness-of-fit statistics and predictive power.

3.3. *Partial proportional odds model*

Different regression techniques have been used to estimate functions f_{ij} included in Equation (6): least squared procedures, multinominal logit, and ordinal regression models (e.g., Rahelizatovo and Gillespie, 1999; Zimmermann and Heckelei, 2012). Since the income level of olive farms in our case study is ranked from the least viable category (i.e., "non-viable", C1) to the most viable category (i.e., "viable in the long term", C3), the dynamics of farm income can be modelled using an ordinal regression model where the farm income category is considered as the dependent variable (y).

Among the different regression models for ordinal responses, the ordinal regression model is the most traditional. However, this model requires the proportional odds or the 'parallel lines' assumption, i.e., the effects of independent variables or beta coefficients are equal at different thresholds (categories) of the dependent variable. This assumption is often violated in the sense that one or more coefficients can differ across values of y. To solve this problem, Peterson and Harrell (1990) proposed the partial proportional odds model (PPOM), where the parallel lines assumption can be relaxed for a subset of explanatory variables in the model. This means the PPOM contains the proportional odds for independent variables that do not violate this assumption, but estimates additional coefficients for those predictors which do not fulfil it. This model provides a more accurate estimation than other available modelling techniques (e.g., multinomial logistic model) given that not all the independent variables have to violate the parallel lines assumption.

The PPOM can be written as:

$$\ln\left(\frac{Pr\{y \leq m|x\}}{Pr\{y > m|x\}}\right) = \tau_m - x\beta - \omega\eta_m \quad (7)$$
$$(1 \leq m \leq M)$$

where m is an ordered response category (3 levels in our empirical study), x and ω are vectors of explanatory variables which meet/do not meet the proportional odds assumption, respectively, β is a vector of unknown regression coefficients corresponding to x, η_m a vector of coefficients corresponding to ω that vary across cutpoint equations and, finally, τ_m the vector of thresholds or cut points for each category of y.

Therefore, in the empirical study carried out, three ordinal regression models were fitted taking each one of the income categories in turn as the dependent variable, and Brant tests (Brant, 1990) were conducted to test the proportional odds assumption for the models as a whole and for each of the explanatory variables. This test compares the β coefficients from m-1 binary logits; the null hypothesis is that these coefficients are equal for all logit models. Therefore, when the null hypothesis is rejected, it means that the β coefficient is violating the parallel assumption and different coefficients should be estimated for each category. The results of these tests showed that a subset of explanatory variables did not fulfil the parallel assumption in every model run, indicating the suitability of the PPOM proposed as the regression technique.

Subsequently, a PPOM was estimated for each dependent variable using the *gologit2* command by Williams (2006) in Stata 14.0 software specifying the *autofit* option. This prompts the *gologit2* command to go through an iterative process, running a series of Wald tests on each independent variable to check if their coefficients are different across equations. The final model imposes constraints on variables that do not violate the proportional odds to keep the same coefficient estimate, while the rest are unconstrained and show different values for each equation.

By estimating these three PPOMs, we seek to determine the explanatory factors of the income dynamics of the olive farms included in categories C1 ("non-viable"), C2 ("viable in the short term"), and C3 ("viable in the long term"). Each model presents two panels representing the probability of staying in the same category or changing to a different (lower or higher) one. Stata selects C3 as the reference category, which means that current and lower categories (C1, and C1 and C2 in the first and the second panels, respectively) are taken as the base group and then compared to the more viable groups (C2 and C3, and C3 in the first and the second panels, respectively).

3.4. *Scenario analysis*

The MCM approach can also be used for ex-ante policy assessment, allowing comprehensive and valid forecasts of future shares of farms included in each income category under different relevant scenarios (Zimmermann *et al.*, 2009). In this regard, the scenario analysis performed here is focused on the off-farm uncontrollable factors to evaluate how market, climatic, and policy conditions could impact the viability of olive farms.

The BASELINE scenario for the analysis proposed is defined by the current olive farms' structure, as described in the last available RECAN subsample for the TF 37 (data gathered in the year 2018), considering average market and climatic conditions for 2009-2018 (i.e., *OPRICE*=100%, *WEATHER*=100%, and *IRATE*=4.24%) and the latest data on policy support (i.e., *CAPDP*=farms' specific CAP payments in 2018). Assuming that farms' structure remains constant, the following three off-farm uncontrollable variables have been considered key for the definition of the scenarios to be analysed: *OPRICE, WEATHER*, and *CAPDP*.

Olive oil prices in the international markets are determined by the laws of supply and demand, but they are also affected by factors such as speculative activity in the market, information asymmetry, currency fluctuations, and government policies (Mili and Bouhaddane, 2021). Interannual imbalances between global olive oil production (affected by events related to weather, pests, and diseases) and demand (influenced by changes in the prices of other substitute vegetable fats), along with other factors shaping the market, lead to a high interannual (between crop

years) price volatility (Abid and Kaffel, 2018). This volatility has meant the olive oil sector in Spain (and elsewhere) has experienced recurrent boom and bust cycles in producer prices, which has jeopardised olive farms' income stability and viability (Gontijo *et al.*, 2020). Moreover, there is no consensus about expected future trends in the price of olive oil since both production and demand are rising worldwide, and it is not clear which will be the dominant driver (Mili and Bouhaddane, 2019). This explains why price volatility has been a major concern for policymakers and justifies the inclusion of *OPRICE* as a key variable to define policy-relevant scenarios.

Over the decade analysed (2009-2018), olive oil prices in Spain ranged from €1.84 to €3.71/kg (average €2.58/kg). For this reason, two feasible price scenarios are considered. First, supposing that an increase in world production (modern high-density and super-high-density groves) would lead to a downward trend in prices, an average price of €2.00/kg is proposed (scenario OP_2EUR), with the variable *OPRICE* taking the value of 77.67%. Second, if increasing demand were to be the dominant driver, a scenario of rising prices is also suggested, considering an average price of €3.00/kg (scenario OP_3EUR), where *OPRICE* would be equal to 116.51%.

The temperatures that regulate olive tree phenology (dormancy period, flowering, and fruit maturation) and the precipitation that determines water availability for olive trees grown under rainfed conditions (69.9% in Spain) are considered the most important climatic factors conditioning olive yields (Fraga *et al.*, 2021). Thus, interannual variations in local weather conditions affect olive yields, both directly (depending on extreme events such as frosts or heatwaves) and indirectly (by influencing the incidence of pests and diseases), thereby determining olive farms' revenue and income. Wide interannual fluctuations in temperature and rainfall, and thus large variations in olive oil production, are distinctive features of the Mediterranean climate. However, according to the Intergovernmental Panel on Climate Change, future climate projections point to the Mediterranean Basin as a climate change "hotspot", where temperatures will continue to rise and precipitation patterns will shift (IPCC, 2015). These warming (meaning higher evapotranspiration and water demand) and drying (i.e., less water availability) trends are expected to strongly affect olive yields in Spain and all other Mediterranean countries (Arenas-Castro *et al.*, 2020; Cabezas *et al.*, 2021). For the Spanish case, a substantial decrease is projected in rainfed olive yields (down by 45%) (Fraga *et al.*, 2020). This evidence leads us to consider *WEATHER* as another key variable to define future scenarios. Thus, we analyse scenarios in which rainfed olive yields will be reduced by 20% (scenario YIELD-20%, where *WEATHER*=80%) and 40% (scenario YIELD-40%, where *WEATHER*=60%). The former scenario assumes technology innovation and adaptation measures will be able to minimise the negative effects of climate change, while the latter assumes such strategies will not be implemented.

Farm incomes in the EU have traditionally benefited from strong public support through the CAP. In the case of Spanish olive farming, the estimated Producer Subsidy Equivalent (PSE, an indicator measuring total monetary transfers to agricultural producers) reaches, on average, 42% of the gross olive producer revenues (Júdez *et al.*, 2017). Most of this public support for olive growers is received through decoupled payments per hectare, set based on past references (historical model). As a result, the average Spanish olive grower currently receives far more in CAP payments (€475.44/ha, RECAN, 2020) than the average Spanish farmer (€266.84/ha, RECAN, 2020). However, the new CAP reform has introduced updated regulations aimed at ensuring more equitable support for all European farmers. The required convergence in decoupled payments will lead to a reduction in the value of payment entitlements that exceed the national average, as is the case of olive growers (Chousou *et al.*, 2020). This likely reduction in the level of support will also negatively impact olive farms' income, which justifies the selection of *CAPDP* as another key variable worth considering when defining policy-relevant scenarios. Thus, a scenario involving a 30% reduction in these payments for all olive farms is pro-

posed (scenario CAP-30%, where *CAPDP* is calculated for each farm as 70% of the CAP payments received in 2018). Additionally, taking into account that the reductions in decoupled payments will be targeted on the basis of farm size (i.e., the introduction of the new redistributive payment for the first hectares), another CAP scenario is suggested in which there is a 50% reduction in CAP support, but with this cut only being implemented after the first 10 of the hectares for which the farmer is entitled to receive payments (scenario CAP-50%+10HA, where *CAPDP* is calculated for each farm depending on the CAP payments received in 2018 and its size).

The scenarios proposed above are illustrative of the versatility of MCM for ex-ante policy analysis. In fact, as the reader might suppose, any other scenario affecting the variables explaining olive farm income dynamics could be defined for future predictions.

Considering the values of the explanatory variables for the base year (t=k, the year 2018 in our case study) in each scenario, the PPOM (Equation (7)) to be estimated can be used to predict the probability of the movement of each farm between income categories ($\hat{p}_{ij}^{t}$). These predictions give us the TPMs P^t for each scenario, and thus farm distribution among categories for the next year (t=k+1, the year 2019 in our case study):

$$X^k \times P_{scenario\_X}^{k} = X^{k+1 \text{ under } scenario\_X} \quad (8)$$

However, this kind of prediction for the next year is not very useful since the results obtained would be out of date by the time they are calculated, and they do not reflect the actual impact of the scenarios considered, since these results for the k+1 period are highly dependent on the initial farm distribution (X^k). For this reason, it is worth assuming that the variables defining the scenarios will remain constant for the next m years, until the farm distribution became stationary; that is, when the distribution X^t remains constant for any $t \geq k + m$:

$$X^k \times P_{scenario\_X}^{k} \times P_{scenario\_X}^{k+1} \times \ldots \times P_{scenario\_X}^{k+m-1} = X^{k+m \text{ under } scenario\_X} \quad (9)$$

As the stationary distribution X^{k+m} does not depend on the initial distribution X^k, it reflects the actual impact on farm income of the scenario considered. The scenario analysis is thus aimed at calculating and analysing the stationary distributions for each scenario, allowing us to assess the impact of the proposed changes in the different off-farm uncontrollable factors on the near future viability of Spanish olive farms.

Finally, note that caution should be taken when comparing the stationary distribution under the BASELINE scenario with those resulting from the different policy scenarios proposed. It is worth recalling that the latter results do not take into account possible responses of olive growers to the scenario changes in terms of their income and cost structure (farms' structure is assumed to remain constant). Despite this shortcoming, these comparative analyses are useful for exploring the primary effects of the three factors studied on the viability of the farms analysed (Vrolijk *et al.*, 2010).

4. Results and discussion

4.1. *The dynamics of olive farm income: transition probabilities*

The RECAN annually collects data from a rotating panel of farms. As shown in Table 3, for the case of the TF 37, olive farms remain in the RECAN panel for varying lengths of time. In fact, only 111 out of the 576 olive farms sampled from 2009 to 2018 have remained in the TF 37 annual subsamples for the whole period. In any case, the 3,156 observations collected in the TF 37 annual subsamples throughout this decade yield 2,555 interannual observations (i.e., single farms sampled in two consecutive years) to analyse the dynamics of farm income. These interannual observations make it possible to account for single farm movements between farm income categories from year t-1 to year t (m_{ij}^{t}) and regress the corresponding transition probabilities (p_{ij}^{t}) as ordinal dependent variables with the set of independent variables proposed (Z^t) using the PPOM approach, as explained in Equation (7).

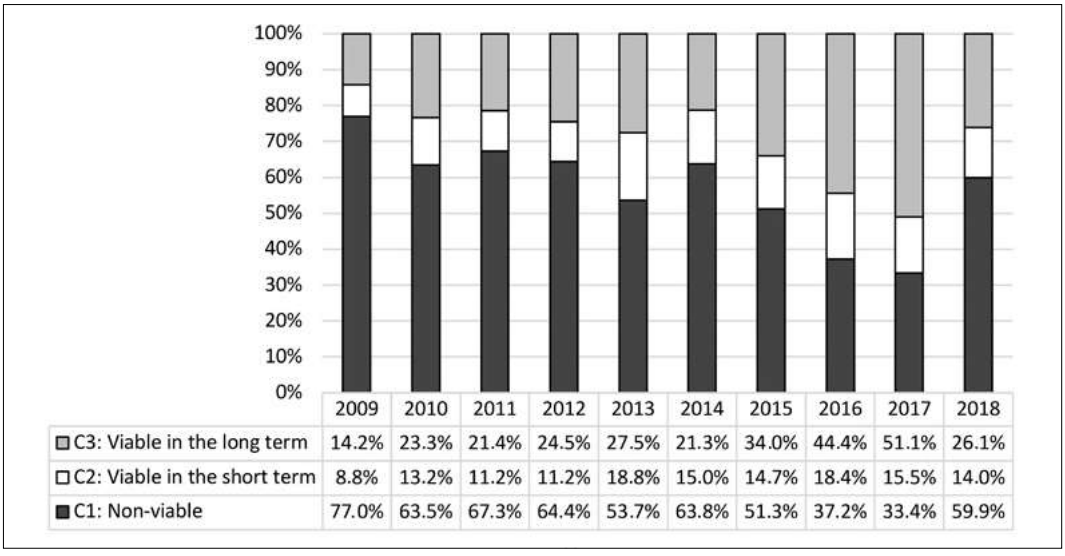
Table 3 - Farms included in the TF 37 (specialized olive farms) subsamples from 2009 to 2018.

Consecutive years in the subsample	*Num. of farms*	*% farms*	*Num. annual observations*	*Num. interannual observations*
1	84	14.6%	109	0
2	35	6.1%	70	35
3	58	10.1%	174	116
4	81	14.1%	324	243
5	33	5.7%	165	132
6	31	5.4%	186	155
7	131	22.7%	917	786
8	7	1.2%	56	49
9	5	0.9%	45	40
10	111	19.3%	1,110	999
Total	*576*	*100.0%*	*3,156*	*2,555*

Using the data from this unbalanced panel of farms could lead to some attrition bias as olive growers voluntarily leaving the RECAN sample cannot be controlled for, and their replacement could generate some sampling noise. However, as pointed out by Barnes *et al.* (2015), this bias is found to be low since the average farm remains in the sample for a reasonable length of time (70% of olive farms remain in the RECAN sample for 4 years or more). Thus, interannual observations obtained as explained above can be judged suitable enough for implementing the microdata MCM approach proposed.

Figure 1 shows the proportions of the olive farms included in the empirical analysis (i.e., those with interannual observations available; n=2,555) classified as "non-viable" (C1), "viable in the short term" (C2), and "viable in the long term" (C3) from 2009 to 2018. As expected, these shares fluctuate over the course of the decade under analysis. For instance, the proportion of "viable in the long term" farms ranges from

Figure 1 - Distribution of farms among farm income categories from 2009 to 2018.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
C3: Viable in the long term	14.2%	23.3%	21.4%	24.5%	27.5%	21.3%	34.0%	44.4%	51.1%	26.1%
C2: Viable in the short term	8.8%	13.2%	11.2%	11.2%	18.8%	15.0%	14.7%	18.4%	15.5%	14.0%
C1: Non-viable	77.0%	63.5%	67.3%	64.4%	53.7%	63.8%	51.3%	37.2%	33.4%	59.9%

51.1% in 2017 to only 14.2% in 2009, while the share of "non-viable" farms varies from 77.0% in 2009 to 33.4% in 2017. As will be analysed in the next section, these fluctuations can be explained by off-farm uncontrollable factors affecting olive oil price (market conditions) or olive yields (weather conditions), and also by farm factors such as farm size, production technology, or the farmer's management skills.

Taking the three income categories proposed, the MCM approach was implemented by shaping the TPMs P^t as follows:

$$P^t(\hat{p}_{ij}^t) = \begin{pmatrix} \hat{p}_{C1,C1}^t & \hat{p}_{C1,C2}^t & \hat{p}_{C1,C3}^t \\ \hat{p}_{C2,C1}^t & \hat{p}_{C2,C2}^t & \hat{p}_{C2,C3}^t \\ \hat{p}_{C3,C1}^t & \hat{p}_{C3,C2}^t & \hat{p}_{C3,C3}^t \end{pmatrix} \quad (10)$$

Available RECAN microdata allow the calculation of the maximum likelihood estimators of non-stationary transition probabilities $\hat{p}_{ij}^t$ on an annual basis following Equation (5). Thus, considering the initial farm distribution X^0 (related to the year 2009), and the TPMs P^t from t=1 (year 2010) to t=9 (year 2018), the final farm distribution X^9 (the year 2018) can be expressed using Equation (3) as follows: $X^0 \times P^1 \times P^2 \times ... \times P^9 = X^9$.

Table 4 shows the average transition probabilities over time for the period analysed (the diagonal is shaded), along with the corresponding standard deviations. Transition probabilities show both high variability across categories and high variability over time.

The highest values in Table 4 are found on the diagonal (except for C2) and represent the probabilities of remaining in the same income category as in the year before. In other words, viable (non-viable) farms tend to remain viable (non-viable) in the following year. This pattern is widely seen in TPMs representing economic phenomena, and in our case study indicates that single farms 'resist' transitioning to other categories. This could be explained by the fact that their income level is strongly influenced by the structural features of olive farms (olive growing is based on a perennial crop for which it is hard to make changes in production technology in the short term). These results also suggest transitions of olive farms between income categories are mainly caused by off-farm uncontrollable factors, such as the price of olive oil, weather conditions determining olive yields, and CAP payments. In any case, these hypotheses will be tested in the next section.

The income category C2 is the exception (aggregated $\hat{p}_{C2,\,C2}^t$=22.4%, while aggregated $\hat{p}_{C2,\,C1}^t$ and $\hat{p}_{C2,\,C3}^t$ are higher than 30%), which can be explained by the relative 'narrowness' of this category (i.e., the short-range of farm income defining the requirements for inclusion in this category: $PI1<1$ and $PI2>1$). In fact, only 14.5% of the interannual observations taken into account (371 out of 2,555) are considered "viable in the short term" in the year t-1. This means that even small changes in the variables determining the dynamics of farm income lead "viable in the short term" farms to transition to another income category. Furthermore, this situation also explains why probabilities adjacent

Table 4 - Transition probabilities (p_{ij}^t) and standard deviations over time.

Profitability category in year t-1	*Profitability category in year t*	*C1*	*C2*	*C3*
C1: *Non-viable*	Average	71.6%	14.0%	14.5%
	St. Dev.	0.084	0.053	0.056
	Num. observations	1,010	197	201
C2: *Viable in the short term*	Average	42.8%	22.4%	34.7%
	St. Dev.	0.216	0.091	0.148
	Num. observations	160	85	126
C3: *Viable in the long term*	Average	22.2%	16.8%	61.0%
	St. Dev.	0.216	0.091	0.148
	Num. observations	195	117	464

to the diagonal (i.e., indicating the relative frequency of transition to neighbouring categories) are not higher than those farther away from the diagonal (i.e., indicating the relative frequency of transition from C1 to C3 or C3 to C1), as is usually found in TPMs.

4.2. *Partial proportional odds models*

Table 5 displays the coefficients (β) and odds ratio (OR) estimates for the independent variables considered for each of the three estimated PPOMs (section 3.3).

Goodness-of-fit statistics are also reported for the three models, showing good values for all these measures. The LR χ^2 test allows us to reject the null hypothesis that the performance of the estimated model is similar to a null model with only the intercept, thus indicating the overall estimated model is statistically significant. McFadden's pseudo R^2 (or LR index) ranges between 19.7% and 22.9%. The count statistic, which reports the proportion of correct predictions, fluctuates between 60.3% (model C2 has the worst predictive potential) and 73.6-73.5% for models C1 and C3, respectively. These values both for McFadden's R^2 and Count can be considered fairly high when compared with other papers that also use PPOM regressions (O'Connell and Liu, 2011). Finally, Log-likelihood at zero and at convergence, as well as Akaike (AIC) and Bayesian information criterion (BIC), are statistics used to compare models. All these statistics (except for LL at zero, which logically stays the same) present better results here than in the initial ordinal logit regression models, confirming that the PPOM provides a more robust estimation.

When interpreting the results of each panel in Table 5, the coefficients are equivalent to those of a binary logit model where categories 1 to m are coded as zero (as the base group) and categories $m+1$ to M are coded as one. Positive coefficients or odds ratios greater than one mean that higher values of an explanatory variable increase the probability of a farm moving to a higher category than the current one. Negative coefficients or odds ratios lower than one imply that the higher the value of the independent variable, the higher the probability of the farm staying in the current category or moving to a lower one (Williams, 2006).

According to the PPOM estimates, the variables *OPRICE*, *WEATHER*, *CAPDP*, and *OUTSOUR*, all of which have positive and statistically significant coefficients (i.e., odds ratios significantly above unity) in the three models, are factors that have a positive impact on olive farm income. That is, higher values of these variables (i.e., good weather conditions, high prices for olive oil, high CAP decoupled payments, and a large share of agricultural practices subcontracted) imply an increase in the probability of moving from categories C1 or C2 to the most viable category, C3, or simply staying in the latter. On the other hand, the variables *ICINT* and *FAMLAB* are also significant in all models, but their coefficients are negative (i.e., odds ratio significantly below one). This means a higher probability of the farm moving to a worse income category for higher values in these variables (i.e., intensive use of intermediate consumption inputs and family labour representing a high percentage of total farm labour).

Some independent variables do not have fixed coefficients in the two panels for each model: *SPEC*, *AGSUIT*, *CAPINT*, and *LANDOWN* in model C1; *SPEC, AGSUIT*, and *CAPINT* in model C2; and *FSIZE*, *AGSUIT*, *DEBEQRAT*, and *FAMLAB* in model C3. This means they do not meet the parallel lines assumption, and thus they can show a significant coefficient and OR estimate in one panel and non-significant ones in the other panel.

In the first model explaining the income dynamics of farms included in category C1 (non-viable), *SPEC* and *AGSUIT* show positive and statistically significant coefficients in both panels, with higher values in the second one, which reports coefficients related to categories C1 and C2 *vs*. C3. Consequently, the higher these two variables, the higher the probability of moving from the non-viable category to viable in the short term or viable in the long term, and the probability of changing from non-viable or viable in the short term to the viable in the long term category is even higher. Moreover, in this first model, the variable *LANDOWN* has a significant negative coefficient

Table 5 - Coefficients and OR estimates for PPOMs.

	C1: Non-viable		*C2: Viable in the short term*		*C3: Viable in the long term*	
C1 vs. C2 and C3	*Coef.*	*Odd Ratio*	*Coef.*	*Odd Ratio*	*Coef.*	*Odd Ratio*
AGE	0.006	1.006	0.039 **	1.039 **	0.028 ***	1.028 ***
AGTRAIN	0.380 *	1.462 *	-0.273	0.761	*-0.415*	*0.661*
FAMLAB	-2.541 ***	0.079 ***	-2.457 ***	0.086 ***	*-3.801* ***	*0.022* ***
LANDOWN	*0.119*	*1.126*	*0.371*	*1.449*	*-0.407*	*0.665*
FSIZE	0.004	1.004	0.002	1.002	*0.004*	*1.004*
AGSUIT	*0.002* ***	*1.002* ***	*0.000*	*1.000*	*0.000*	*1.000*
SPEC	*1.804* ***	*6.071* ***	*-0.864*	*0.422*	*2.891* **	*18.007* **
ICINT	-0.002 ***	0.998 ***	-0.002 ***	0.998 ***	-0.002 ***	0.998 ***
CAPINT	0.000	1.000	*1.52E-05*	*1.000*	0.000	1.000
OUTSOUR	5.021 ***	151.604 ***	3.199 *	24.516 *	5.619 ***	275.484 ***
DEBEQRAT	-0.176	0.838	46.253	1.2E+20	*-35.613* *	*0.000* *
OPRICE	1.659 ***	5.256 ***	3.003 ***	20.137 ***	3.530 ***	34.127 ***
WEATHER	0.622 **	1.862 **	1.492 ***	4.448 ***	0.774 ***	2.168 ***
CAPDP	0.002 ***	1.002 ***	0.002 ***	1.002 ***	0.002 ***	1.002 ***
Constant	*-5.258* ***	*0.005* ***	*-4.540* **	*0.011* **	*-5.578* ***	*0.004* ***
C1 and C2 vs. C3	*Coef.*	*Odd Ratio*	*Coef.*	*Odd Ratio*	*Coef.*	*Odd Ratio*
AGE	0.006	1.006	0.039 **	1.039 **	0.028 ***	1.028 ***
AGTRAIN	0.380 *	1.462 *	-0.273	0.761	*0.283*	*1.327*
FAMLAB	-2.541 ***	0.079 ***	-2.457 ***	0.086 ***	*-2.294* ***	*0.101* ***
LANDOWN	*-0.582* *	*0.559* *	*0.371*	*1.449*	*-0.407*	*0.665*
FSIZE	0.004	1.004	0.002	1.002	*0.008* **	*1.008* **
AGSUIT	*0.003* ***	*1.004* ***	*0.002* **	*1.002* **	*0.001* ***	*1.001* ***
SPEC	*3.606* ***	*36.815* ***	*2.351* *	*10.495* *	*2.891* **	*18.007* **
ICINT	-0.002 ***	0.998 ***	-0.002 ***	0.998 ***	-0.002 ***	0.998 ***
CAPINT	0.000 ***	1.000 ***	*-6.16E-05* *	*1.000*	0.000	1.000
OUTSOUR	5.021 ***	151.604 ***	3.199 *	24.516 *	5.619 ***	275.484 ***
DEBEQRAT	-0.176	0.838	46.253	1.2E+20	*7.446*	*1,713.6*
OPRICE	1.659 ***	5.256 ***	3.003 ***	20.137 ***	3.530 ***	34.127 ***
WEATHER	0.622 **	1.862 **	1.492 ***	4.448 ***	0.774 ***	2.168 ***
CAPDP	0.002 ***	1.002 ***	0.002 ***	1.002 ***	0.002 ***	1.002 ***
Constant	*-7.894* ***	*0.000* ***	*-9.942* ***	*0.000* ***	*-8.735* ***	*0.000* ***
N. of observations	1,219		343		732	
LR χ^2	326.92***		148.01***		269.10***	
Pseudo R^2	0.197		0.199		0.229	
Count	0.736		0.603		0.735	
LL at zero	-998.54		-371.56		-587.01	
LL at convergence	-802.96		-297.56		-452.46	
AIC	1,644.39		633.12		946.92	
BIC	1,746.51		706.03		1,043.43	

Note: Coefficients and Odds Ratios of explanatory variables that do not meet the parallel assumption are in italics.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

but only in the second panel, suggesting that the probability of moving directly to the viable in the long term category increases when the percentage of owned land increases. Finally, the variable *AGTRAIN* also shows significant coefficients, with the same positive value in both panels since this variable meets the proportional odds assumption in this model. This result means that a farmer with an agricultural degree managing a farm initially included in the non-viable category (C1) has a higher probability of the farm moving to a more viable one (C2, C3), while farms initially included in C2 also have the same higher probability of moving to C3.

Regarding the second model explaining the income dynamics of farms included in category C2 (viable in the short term), there are three variables which violate the proportional odds assumption showing significant coefficients (*SPEC, AGSUIT*, and *CAPINT*), although these coefficients are only significant in the second panel (related to categories C1 and C2 *vs*. C3). *SPEC* and *AGSUIT* have significant positive coefficients implying that higher values of these two variables (i.e., higher share of olive farming area and better local pedoclimatic conditions for olive production, respectively) increase the probability of the farm moving to the viable in the long term category (C3). The variable *CAPINT* shows a negative and significant parameter, indicating an increasing probability of moving directly to the viable in the long term category when the capital intensity increases. Additionally, in this second model, there is also a variable (*AGE*) meeting the proportional odds assumption showing positive and significant coefficients in both panels. This means that older farmers have a higher probability of staying in the C2 category or moving to the viable in the long term category (C3).

Lastly, the model explaining the income dynamics of farms included in category C3 (viable in the long term) also shows three variables that do not meet the parallel assumption and that show significant coefficients: *FSIZE*, *AGSUIT*, and *DEBEQRAT*. The variables *FSIZE* and *AGSUIT* have positive coefficients but they are only significant for the second panel, meaning a higher probability of staying in the viable in the long term category (C3) when these variables have higher values. The variable *DEBEQRAT* presents a significant parameter only in the first panel (related to categories C1 *vs*. C2 and C3) showing a negative value. Thus, a rise in the value of this factor (i.e., higher debt) increases the probability of moving from category C3 directly to category C1. In addition, two variables (*SPEC* and *AGE*) meeting the proportional odds assumption exhibit significant coefficients in this model. These two variables have positive coefficients, meaning that those olive farms with higher values for both variables have a higher probability of remaining in category C3.

Most of the results reported above are aligned with those found in the literature focused on other agricultural systems elsewhere. Thus, our PPOM estimates corroborate the crucial role in farm income dynamics played by off-farm uncontrollable factors such as the agricultural commodity prices (e.g., Baek and Koo, 2009; Zimmermann and Heckelei, 2012) and the subsidies granted by the CAP (e.g., Biagini *et al.*, 2020; Piet and Desjeux, 2021).

Moreover, the empirical results obtained also confirm that much of the interannual variations in farm income can be explained by farm-specific structural factors as the suitability of the farmland for agricultural production (e.g., Zimmermann and Heckelei, 2012; Allanson *et al.*, 2017), the farm's productive specialisation (e.g., Barnes *et al.*, 2020; Biagini *et al.*, 2020), the age of the farmer (e.g., Gloy and LaDue, 2003; Piet and Desjeux, 2021), or the farmer's managerial ability related to his/her agricultural training (e.g., Allanson *et al.*, 2017; Barnes *et al.*, 2020).

However, our results differ from other common findings in the literature. Probably the most notable discrepancy is that farm size did not yield significant coefficients (except in the second panel of model C3), contradicting evidence from many previous studies (e.g., Allanson *et al.*, 2017; Coppola *et al.*, 2020) showing increasing return to scale in farming production. Two circumstances could explain this divergence. First, it is worth noting that very small olive farms (those with an SGM of less than 8,000 Euros per year or "non-commercial" farms) are not included in the RECAN samples. Thus, our results just

suggest that, for an economic dimension above the threshold to be considered a commercial farm, the differences in return to scale are rather small given that available olive production technologies can be adapted to a wide range of farm sizes. The second explanation is related to the insensitivity of olive production to labour and intermediate consumption (i.e., changes in labour and intermediate consumption cause little difference in the total output obtained). Our results suggest that smaller olive farms are more likely to opt for more intensive production (i.e., higher labour −usually family labour− and intermediate consumption input use) as a strategy to obtain higher output per hectare and thus compensate for any possible handicap regarding returns to scale. However, it has been proven that this is not an effective strategy since higher values in the variables *ICINT* and *FAMLAB* increase the probability of worsening the farm viability, which can only be explained by the farmers' undervaluation of the labour, land, and capital inputs they contribute to farming activities. Conversely, our results show a positive impact on farm viability of the outsourcing strategy (i.e., subcontracting more complex agricultural practices). To the best of the authors' knowledge, no such evidence on outsourcing has been reported before, although this finding could probably only be translated to other agricultural systems with a similar level of managerial complexity to modern olive production.

Finally, other factors commonly reported in the literature as affecting farm income, such as land ownership (e.g., Barnes *et al.*, 2015; Biagini *et al.*, 2020) or the farm business leverage (e.g., Gloy and LaDue, 2003; Allanson *et al.*, 2017), were not found to be significant in our case study. This divergence can probably be explained by specific characteristics of the Spanish olive sector, which largely relies on owned farmland (average *LANDOWN*=87.1%) and owned capital resources (average *DEBEQRAT*=1.5%).

4.3. *Scenario analysis*

The three PPOM obtained in the previous section allowed us to estimate the transition probabilities between farm categories ($\hat{p}_{ij}^{t}$) and the TPMs P^t for any year $t \geq k+1$. Thus, the BASELINE scenario and each of the six alternative scenarios proposed have been predicted following Equation (9), according to the different assumptions for the specific explanatory factors involved in the scenario analysis (*OPRICE*, *WEATHER*, and *CAPD*). Table 6 shows the farm distributions obtained once they became stationary. In all cases, the stationary distributions were reached after just 2 years (i.e., for $t = k + 2$).

The BASELINE scenario shows a farm distribution that is fairly well balanced between categories C1 and C3, although the share of farms that are viable in the long term is 3% higher. Thus, under the business-as-usual scenario, a clear duality is observed, with the commercial olive farms being evenly split into viable in the long term and non-viable categories. Bearing in mind the results detailed above, the former farms are those with more suitable farmland, more specialised in olive production and managed by older and better trained olive growers who avoid implementing excessive intensive production techniques while subcontracting more complex agricultural practices. The latter farms are those

Table 6 - Results for scenario simulations: farms distribution among profitability categories.

Scenario	*C1*	*C2*	*C3*
BASELINE	46.2%	4.3%	49.5%
OPRICE_2EUR	61.7%	5.2%	33.0%
OPRICE_3EUR	37.9%	4.9%	57.1%
WEATHER=80%	50.3%	3.7%	46.0%
WEATHER=60%	53.5%	3.0%	43.5%
CAP-30%	53.5%	4.9%	41.6%
CAP-50%+10HA	54.1%	4.0%	41.9%

that do not display said features.

Category C2 is practically non-existent, accounting for just 4.3% of the farms, a low portion also seen in all other scenarios (in all cases, C2 lies between 4.0% and 5.2%). This can be explained by the relative 'narrowness' of this category as explained above, meaning that in stationary states the farms tend to be classified into one of the two extremes categories (non-viable −C1− or viable in the long term −C3) according to their specific characteristics and the assumptions made in each scenario.

As expected, the variable capturing olive oil prices (*OPRICE*) causes the largest changes in farm distributions. Thus, in the OPRICE_2EUR scenario, the percentage of non-viable farms (C1) increases to 61.7%, while only one-third of the farms would remain viable in the long term. Conversely, in the favourable price scenario considered (OPRICE_3EUR), the percentage of non-viable farms (37.9%) would be the lowest among all the scenarios considered and, simultaneously, the highest percentage of farms that are viable in the long term would be reached (57.1%).

Regarding the variable *WEATHER*, a 20% worsening (i.e., WEATHER=80% scenario) leads to a 4 percentage point increase in non-viable farms compared to the BASELINE scenario, which corresponds to a 0.6 percentage point reduction in farms that are viable in the short term and 3.5 percentage point drop in ones that are viable in the long term. An additional 20% reduction in the *WEATHER* variable (i.e., WEATHER=60% scenario) would lead to a further increase of 3.2 percentage point in non-viable farms (7.2 percentage point increase over the BASELINE scenario), while category C3 would drop another 2.5 percentage point (6 percentage point decrease over the BASELINE scenario). All these estimations describing the potential impact of climate change suggest that Spanish olive farms are rather resilient, especially the third of the Spanish olive area under irrigation, where climate change impacts are expected to be minimised.

Finally, CAP payments also exert a considerable influence on the farms' distribution among income categories. A 30% decrease in the variable *CAPDP* (i.e., CAP-30% scenario) yields a similar influence to that caused by the WEATHER=60% scenario, with the same percentage of farms in category C1; however, the situation is worse in terms of farms that are viable in the long term, which decrease to 41.6% in this scenario (8.1 percentage point less than in the BASELINE scenario). These results can be taken as evidence that olive farm income is highly dependent on CAP subsidies. However, it is worth noting that in the scenario with a 50% reduction in the CAP decoupled payments variable, but with this cut not affecting payments granted for the first 10 hectares, the impact on farm distribution would be very similar to the CAPD-30% scenario, with variations below 1 percentage point in all three categories. This provides evidence that new CAP payments could be designed to minimise the impact of any support cut on the income distribution of olive farms.

5. Concluding remarks

This paper presents a relevant theoretical contribution relating to the analysis of farm income dynamics. By combining the Markov chain and ordinal regression models, the proposed approach allows us to determine which factors explain interannual changes in farm income (i.e., individual farm movements between income categories) and predict the impact of future scenarios on individual farms income (i.e., stationary income category). The empirical application of this approach to Spanish olive farms has shown it is sound and easily replicable for any other farming sector in the EU using the data provided by the FADN (or similar accountancy data networks in individual countries). Moreover, the empirical case study performed has also provided evidence that the results obtained using this approach are useful for ex-ante policy analysis supporting policy decision-making.

The empirical results obtained have shown, on the one hand, that interannual income variations in Spanish olive farms are determined by a combination of off-farm uncontrollable factors such as the price of olive oil, the annual weather conditions, and the CAP subsidies. Other factors also influencing the dynamics of these farms' income are: a) farm-specific structural features such as

the agronomic suitability of the farmland and the farm's productive specialisation; b) farmer-specific characteristics such as age and agricultural training; and c) management factors such as the production intensity and the outsourcing strategy. However, it is worth remarking that farm size has not yielded significant results in the case of the Spanish olive sector, unlike what has been found in many other agricultural sectors.

On the other hand, the application of the method proposed to forecast the distribution of farms among income categories under several alternative scenarios has provided useful results that can support policy analysis. Future scenarios proposed show that the viability of Spanish olive farms is very sensitive to market conditions (i.e., olive oil prices), such that an increase (decrease) in olive oil prices contributes to a rise (reduction) in the proportion of viable olive farms. Likewise, the worsening of climatic conditions (i.e., decrease in olive yields) and policy support (i.e., reduction of CAP decoupled payments) leads to a decrease in the share of viable farms, although these two explanatory variables are less relevant than olive oil prices.

Regarding the limitations of the empirical analysis performed, it is worth mentioning the 2-3 years lag in the FADN data (i.e., the latest data currently available are for the year 2018). In this regard, a faster release of annual accountancy data could be very valuable.

Two avenues for future research are suggested. First, a comparative analysis with other agricultural sectors and/or other countries could be carried out. This could yield useful information for policy-makers to support the design and implementation of policy instruments, and also for farmers themselves, who would be able to distinguish between the uncontrollable and controllable factors that really influence income generation and competitive position. Second, from a methodological perspective, some refinements in the methodological approach could be tested (e.g., a farm typology with more viable categories), and the proposed approach could be extrapolated to analyse the dynamics of other farm outcomes (e.g., environmental performance measured using agri-environmental indicators).

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Costs and benefits of sustainability-oriented innovation in the agri-food industry: A review

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Abstract

In light of the increasing demand for sustainable development, the agri-food industry is under pressure to make the transition towards sustainability. Innovation has been identified as a key driver for this transformation. However, the agri-food industry, which in many countries is dominated by small and medium-sized enterprises, is highly sensitive to the benefits, costs and potential risks of sustainability-oriented innovation. At the same time, because of the low propensity of countries in the Mediterranean region to innovate, an in-depth exploration of innovation is necessary. This paper presents a review of the costs and benefits of specific sustainability-oriented innovations, not only economic but also social and environmental, to provide a guide for researchers and adopters of sustainability-oriented innovations in the Mediterranean region. To achieve this goal, this paper classifies the elements being reviewed according to the nature of the innovation and stages of the product life cycle it covers. This paper has implications for farmers, business managers, regulators and policy makers in the Mediterranean region.

Keywords*: Sustainability-oriented innovation, Agri-food industry, Benefits, Costs.*

1. Introduction

The need for sustainable development is growing since it can address a range of worsening global issues such as wasted resources, environmental degradation and social inequality. Brundtland (1987) defines the concept of sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainable development requires companies to consider the overall development of the economy, environment and society, which is the "triple bottom line" (Elkington, 1994). The agri-food industry is one of the most valuable and influential industries in any country, contributing to national welfare, gross domestic product and social life. The agri-food industry is closely linked to the natural environment. Not only does it directly participate in the use and consumption of natural resources such as water and soil, which have a huge impact on the natural environment (De Luca *et al.*, 2018), but it also suffers from

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the ill effects of the deterioration of the natural environment and therefore has an extremely high demand for environmental improvement. For example, the Mediterranean region, which is one of the regions where food systems are most affected by climate change, is facing a number of problems, such as water scarcity, degradation of arable land and desertification, and loss of biodiversity (Capone *et al.*, 2021). At the same time, the agri-food industry plays a role in food security and human health issues and is hence an industry of significant social importance. Therefore, to create a sustainable food system there is a need for transformation in sustainability in the agri-food industry. Ikerd (1990) defines sustainable agriculture as "farming systems that are capable of maintaining their productivity and utility indefinitely," and that are "resource-conserving, environmentally compatible, socially supportive, and commercially competitive."

The role of innovation in helping firms transition to sustainability has received considerable attention from academics, regulators and policymakers. In particular, in the agri-food industry, innovation is considered to be an extremely critical link in the transition to sustainable agriculture. Bedeau *et al.* (2021) identify technological innovation as one of four critical levers – multiparty collaboration, data and evidence, technological innovation, and coherent policies and investments – to address the challenges faced by food systems in the Mediterranean region. Hansen and Grosse-Dunker (2013) define sustainability-oriented innovation (SOI) as "the commercial introduction of a new (or improved) product (service), product-service system, or pure service which – based on a traceable (qualitative or quantitative) comparative analysis – leads to environmental and (or) social benefits over the prior version's physical life cycle ('from cradle to grave')." As a result of market and consumer needs, companies in the agri-food industry must innovate sustainably in the product, production and packaging phases to strengthen their corporate image and gain consumer recognition.

It has been highlighted in the literature that sustainability and SOI are beneficial for companies and that there is a positive relationship between the social orientation of companies and their economic and financial performance (Marotta *et al.*, 2017). SOI is also considered to increase the productivity and economic efficiency of agricultural farming, enhancing economic performance for companies and further promoting employment and fair compensation (Iofrida *et al.*, 2018). However, such a positive correlation is not immediately apparent. Ponta *et al.* (2022) perform a study on the relationship between the output of SOI and the economic performance of firms in the agri-food industry and the results show that the output of SOI is positively correlated with economic performance, but the impact occurs years later. Therefore, companies must consider the financial cost and return on investment period when developing and adopting SOI. SOI is also associated with "directional risk". The adoption of SOI possesses technical, commercial, organisational, and social acceptance uncertainties. For example, in terms of social acceptance uncertainties, innovation may bring about issues such as widening socio-economic gaps and gender inequality, especially in developing countries (Bedeau *et al.*, 2021). On the Mediterranean coast, except for the north and west, the region is mostly made up of developing countries, so the social acceptance of innovation is more uncertain. Hence, companies should consider not only the economic aspects when adopting SOI, but also the potential environmental and social impacts of SOI. This is especially the case in the agri-food industry, which is a highly competitive industry where most companies are small and medium-sized enterprises. Both upstream suppliers (especially farmers) and downstream producers and sellers have weak bargaining power and limited ability to differentiate (Cagliano *et al.*, 2016), and are highly sensitive to cost and risk.

Consequently, when agri-food companies undertake research and development and adopt SOI, they must weigh up the costs and benefits, including the economic, environmental, and social aspects. Costs include the capital required for technological development and adoption, yield uncertainty, environmental pollution due to technological shortcomings, negative social benefits and potential future risks; benefits in-

clude potential increases in economic performance, positive environmental impacts, and social performance, such as an improved agri-food supply chain and employment environment. The costs and benefits of SOI vary across sustainability practices. Several scholars currently provide fragmented accounts of the costs and benefits of specific SOIs. Nevertheless, academics have yet to produce a systematic generalisation and summary on this topic. This paper, therefore, provides an up-to-date review of the literature on the costs and benefits of specific SOI in the agri-food industry, to provide guidance on the adoption of different categories of SOI by companies in the agri-food industry. It is worth emphasising, as mentioned above, that the benefits and costs defined in this paper are economic, environmental and social based, not just economic. Nor does this paper provide any specific numerical evidence of benefits and costs at the economic level. Therefore, no specific contribution is made to the economic or financial balance sheet-based assessment. The aim of this paper is to provide an identification and description of the main initiatives and potential returns and costs for firms to implement different types of innovation to improve their sustainability conditions.

The paper is structured as follows:

In section two, different classification categories for SOI in the agri-food industry are established, drawing on the existing SOI classification and the product life cycle stages in which SOI plays a role. In section three of this paper, we collect and screen the kinds of literature about SOI in the agri-food industry through the Scopus database and then classify each SOI according to the groups established in section two. Section four of the paper contains a summary and discussion of the costs and benefits of each SOI. The conclusions are set out in section five.

2. Framework: designing the classification of SOI in the agri-food industry

In this section, we build a framework to categorise specific SOIs in the agri-food industry covered in the literature. The purpose of the classification is to provide a clearer picture of the types of SOI and the different stages in which they function, as well as to provide a more systematic guide to the adoption of different SOIs by companies in the industry. In this paper, we will classify SOI using two dimensions: the type of SOI and the stage of the product life cycle.

There are different classification criteria for innovation. According to the type of innovation, Gaudig *et al.* (2021) classify innovation into technological innovation, marketing innovation, product innovation and service innovation; Klewitz and Hansen (2014) classify innovation into three categories: process innovation, organisational innovation and product innovation. According to the degree of innovation, innovation can be classified as radical, incremental or reapplied (El Bilali, 2019); Adams *et al.* (2016) classify innovation into three levels: operational optimisation, organisational transformation and system building. When categorising innovation according to its drivers, innovation is classified as technology-driven, market-pull, design-driven, regulatory-driven/pull or value-driven (Cagliano *et al.*, 2016). Most of the literature classify SOI based on only one criterion as listed, with only a small amount of literature using two dimensions to classify SOI, for example Hansen and Grosse-Dunker (2013) classify SOI according to the goal dimension and the lifecycle dimension. It's because that they don't discuss a large number of specific SOIs. However, the subsequent part of this paper deals with a large number of specific SOIs and it would be difficult to organise the article clearly by following only a single criterion. Therefore, we choose to classify SOI using a two-dimensional classification.

In this paper, in the first dimension, the classification is made according to the type of innovation as Gaudig *et al.* (2021), Klewitz and Hansen (2014). Combining the work of different scholars, the types of innovation mainly include product and service innovation, process innovation, organisational innovation, marketing, and market innovation, etc. However, according to research on the characteristics of sustainable development in the agri-food industry and based on the results of the literature review below, the current SOIs in this industry are focused on three types, namely process innovation, product

Table 1 - Classification of SOI according to its nature.

Process innovation	*Product innovation*	*Organisational innovation*
Innovative practices in the production process of products or services to reduce environmental impacts and improve eco-efficiency and sustainability. Mainly includes clean production, waste recycling, efficient logistics and other related technologies.	The elimination or improvement of old products or services that have a significant impact on the environment, making improvements or discovering a completely new product or service. The main directions include sustainable products, sustainable labels, packaging and other related innovations.	The reorganisation of the internal systems of the company at the organisational level to promote sustainable development, or to propose new forms of management and new thinking about business operations, to transform old business operation models that are not in line with the concept of sustainable development. The main directions include the establishment of systematic innovation models, supply chain management and stakeholder management.

Source: own elaboration.

innovation and organisational innovation. Therefore, in this paper, according to the classification of Klewitz and Hansen (2014), SOIs are divided into above three groups in Table 1.

In order to give companies in the agri-food supply chain a more direct view of the SOI in their own sector, in the second dimension, we classify SOI according to the 'cradle-to-cradle' (Hansen and Grosse-Dunker, 2013) life cycle stages of the products in which it plays a role. There are five life cycle stages of a product that are important and where the main sustainability impacts occur: supply chain, production, packaging or distribution, use and end of life (Hansen and Grosse-Dunker, 2012). Cagliano *et al.* (2016) argue that companies in the agri-food industry can be divided into three main sectors: agriculture, food processing and distribution. De Luca *et al.* (2018) divide the life cycle of agriculture into the planting sector, the growing sector, the production sector and the end of life. On this basis, this paper divides the life cycle of products in the agri-food industry into one 'cornerstone' and four stages, as shown in Table 2.

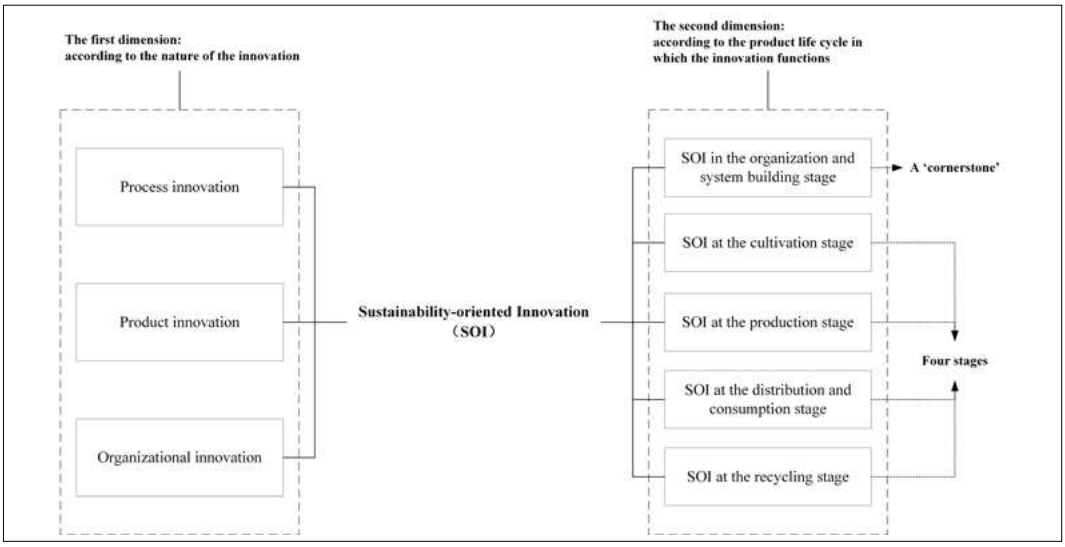
Here, while the decision-making in technology development strategy (TDS) and system building stage is not part of any product life cycle, the com-

Table 2 - Classification of SOI according to the product life cycle stages in which it functions.

Stage	*Definition*
Cornerstone: Decision-making in technology development strategy (TDS) and system building	In this stage, the strategic decisions of the company regarding sustainability are determined.
Stage 1: Cultivation	In this stage, the raw materials for the agri-food products are obtained through cultivation.
Stage 2: Production	In this stage, the raw agricultural products are transformed into agri-food through processing.
Stage 3: Distribution and consumption	In this stage, the agri-food products are packaged and shipped to various distributors or hotels, restaurants, etc., after which they are purchased and used by consumers.
Stage 4: Recycling	This stage actually runs through all three of the previous stages, as any one of them can produce waste or wastewater or greenhouse gases that have an impact on the environment. In the recycling stage, the waste and wastewater are transformed into new raw materials or energy through the recycling system.

Source: own elaboration.

Figure 1 - The classification of sustainability-oriented innovation in agri-food industry.



Source: own elaboration.

pany's strategic decisions about sustainability determine the technological direction of production and the subsequent adoption of SOI. At the same time, sustainability is seen as a system-level issue (Adams *et al.*, 2016) that is not only achievable by one technology or one individual organisation, but rather requires the whole supply chain system to innovate towards sustainability. This stage is therefore defined in this paper as a 'cornerstone'.

This paper, therefore, divides SOI in the second dimension into five groups according to the life cycle of the product: SOI at the cultivation stage, SOI at the production stage, SOI at the distribution and consumption stage, SOI at the recycling stage, and SOI at the decision-making in technology development strategy (TDS) and system building stage.

Combining these two dimensions, we believe that such a classification provides a main line of analysis for the subsequent literature study in this paper and facilitates a categorical discussion in the discussion section to understand the strengths and barriers to SOI adoption within the different segments. It will also help the relevant adopters of each SOI to understand more directly the different types of SOI within the different segments. The classification of SOI in the agri-food industry is shown in Figure 1.

3. Methodology

This paper is a compendium and review of current research on the costs and benefits of SOI in the agri-food industry. In accordance with standard literature research methods, this paper chooses to collect the relevant literature through the Scopus database. The specific method is shown in the Figure 2.

The first step was to obtain research material by searching through the Scopus academic database. The keywords selected for this paper are divided into two parts. The first part is about the description of the agri-food industry. Since the agri-food industry involves many related keywords, we chose "agri*" as the search term, which can cover many keywords related to agriculture, including agriculture, agri-food and so on. In a broad sense, agriculture includes farming, animal husbandry, aquaculture, forestry, etc., while in a narrow sense, agriculture refers specifically to farming. In this paper, we focus our attention on agri-food production in the narrow sense and therefore do not consider agriculture in the broad sense. The second part is about the keywords for sustainability-oriented innovation. The terms used most commonly in academia are "sustainability-oriented innovation", "sustainability-driven innovation" and

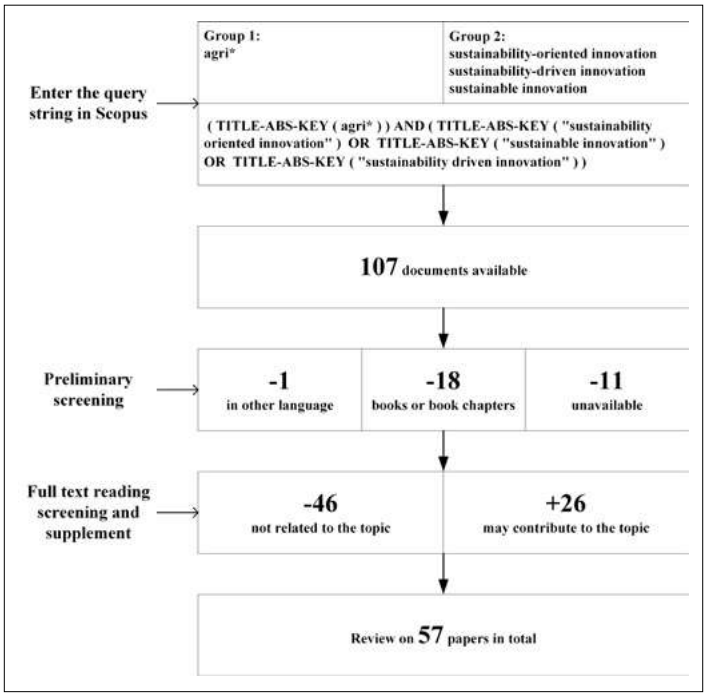


Figure 2. Methodology for literature search and screening.

Source: own elaboration.

"sustainable innovation", so this paper chose these three phrases as search terms. In addition, there are fairly narrow definitions of sustainable innovation, such as eco-innovation, ecological innovation, environmental innovation, frugal innovation, green innovation, inclusive innovation and social innovation which focus on innovation that improves a single aspect of the environment or society. This paper believes that according to the "triple bottom line" theory (Elkington, 1994), sustainable development must be comprehensive and balance the economic, environmental and social benefits. Innovations that focus on a single aspect do not meet this criterion, so the above keywords were excluded from consideration. After completing this step, the result was 107 relevant papers (as of 27 August 2022).

The second step was the preliminary screening of the above literature. In order to make the screening more accurate, this paper did not use the automatic filter in the database and instead screened the 107 papers manually. The screening criteria are divided into three parts. The first part is language, and English was chosen as the only allowed language for this paper. One document was removed under this criterion. The second part was that the target literature should be journal articles, so 18 books or book chapters were excluded. The third part was availability, and the remaining literature was searched through major databases, of which 11 could not be sourced and were therefore excluded. After screening, the remaining 77 articles were available for the next step of the reading and screening.

The third step was to read the full text for screening. In screening methods used by other authors, there may be a step of reading the abstract for screening. However, after reading through this paper it was found that there are few studies directly on the costs and benefits of SOI in the agri-food industry and a large number of descriptions of this topic are scattered in some seemingly irrelevant literature through the abstract. Therefore, this paper considers that filtering through abstracts may result in some important information being missed, so we skipped this step and read the full text directly for screening. The selection criteria for this paper were that the paper must include a description of the costs and benefits of a specific SOI technology, or a study of how a specific organisational innovation has improved the

diffusion and adoption of SOI, as such an improvement is itself a potential benefit that contributes directly to the SOI technology while indirectly contributing to sustainable development. Meanwhile, in the process of reading the full text, this paper found that the literature mentioned or cited in the text was also related to the research topic of this paper. In particular, articles about some specific artificial intelligence, biological and chemical technologies, whose article titles, abstracts and keywords do not explicitly contain keywords related to sustainability-oriented innovation, had been excluded from the scope of this paper. However, these articles do describe the costs and benefits of the technology and can be of great reference value to this paper. Therefore, this paper used the "snowball" (Adams *et al*., 2016) method and included these articles in this review as well. After this screening and supplementation stage, 46 irrelevant papers were removed and 26 relevant papers were added, meaning that finally 57 papers were obtained as the review material for this paper.

Table 3 - The result of classification.

	Classification according to nature			*Classification according to the product life cycle*				
	Process innovation	*Product innovation*	*Organisational innovation*	*Decision-making in TDS and system building*	*Cultivation*	*Production*	*Distribution and Consumption*	*Recycling*
Aljaafreh, 2017	√					√		
Awada & Phillips, 2021	√				√			
Bigliardi 2022	√				√			
Butler & Holloway, 2016	√			Across all stages				
Cagliano *et al.*, 2016		√			√			
Cappelli & Cini, 2021	√				√			
Cappelli, Canessa, & Cini, 2020	√					√		
Cappelli, Guerrini, Parenti, *et al.*, 2020	√					√		
Cappelli, Oliva, & Cini, 2020	√					√		
Cappelli, Oliva, Bonaccorsi, *et al.*, 2020	√					√		
De Boni *et al.*, 2019		√			√			
De Luca *et al.*, 2018	√				√			
Delmas & Gergaud, 2021		√					√	
Dobbs *et al.*, 2011	√				√			
Dyck & Silvestre, 2019			√	√				
Fam & Mitchell, 2013	√				√			
Fargione *et al.*, 2008	√							√
Gao *et al.*, 2020	√				√			
Gaudig *et al.*, 2021	√		√	√				√
Geissdoerfer *et al.*, 2017	√							√
Giller *et al.*, 2009	√				√			
Giua *et al.*, 2022	√			Across all stages				
Greenland *et al.*, 2018	√				√			

	Classification according to nature			*Classification according to the product life cycle*				
	Process innovation	*Product innovation*	*Organisational innovation*	*Decision-making in TDS and system building*	*Cultivation*	*Production*	*Distribution and Consumption*	*Recycling*
Heyes *et al.*, 2020		√					√	
Klewitz & Hansen, 2014			√	√				
Kopytko, 2019	√				√			
Li *et al.*, 2020	√				√			
Long & Blok, 2021			√	√				
Long *et al.*, 2017	√		√	√	√			
Lubell, 2011			√	√				
Marotta *et al.*, 2017		√				√		
Martin-Rios *et al.*, 2021	√		√	√			√	
Meisch & Stark, 2019	√						√	
Orjuela-Garzon *et al.*, 2021			√	√				
Pancino *et al.*, 2019			√	√				
Patrício & Rieder, 2018	√			Across all stages				
Pelse *et al.*, 2018			√	√				
Philippi *et al.*, 2015	√		√	√	√			
Pilloni *et al.*, 2020	√		√	√				√
Ponta *et al.*, 2022			√	√				
Pontieri *et al.*, 2022		√			√			
Raman & Mohr, 2014	√							√
Rana *et al.*, 2021	√						√	
Rejeb & Rejeb, 2020	√						√	
Saberi *et al.*, 2019	√						√	
Sanders *et al.*, 2021	√			Across all stages				
Schoenke *et al.*, 2021			√	√				
Seghieri *et al.*, 2021			√	√				
Sellitto *et al.*, 2021	√				√			
Sparrow & Howard, 2021	√			Across all stages				
Stanco *et al.*, 2020	√		√	√	Across all stages			
Su *et al.*, 2019	√					√		√
Troise *et al.*, 2021			√	√				
Vecchio *et al.*, 2020			√	√				
Wu *et al.*, 2014	√					√		
Yamoah *et al.*, 2021	√				√			
Zhang *et al.*, 2021	√			Across all stages				

Source: own elaboration.

After reading these 57 articles, the SOIs covered in these articles were classified according to the classification criteria established in Chapter 2. The results of the classification of literatures are shown in Table 3.

In Chapter 4, SOIs will be discussed under each category separately, according to the classification.

4. Results and discussion

4.1. *Process innovation*

If we consider the product life cycle involved in process innovation, process innovation can occur throughout the product life cycle at the cultivation, production, distribution/packaging and recycling stages. This section will therefore cover these four stages.

4.1.1. *Process innovation across the life cycle*

Digital technologies are currently a hotly discussed topic. Digitisation of agricultural systems cuts across every aspect of the agri-food industry, enables the technological optimisation of every aspect of the whole system and minimises the environmental impact of agriculture (Zhang *et al.*, 2021). For example, smart farming technologies, intelligent devices in cyber-physical systems, can improve farm management and generate a wealth of data that can be used not only on the farm but also throughout the whole supply chain (Giua *et al.*, 2022). The adoption of artificial intelligence technologies (AI), which analyse large amounts of data through intelligent machines or software that automatically identify and respond to the environment they are in and act accordingly, is considered to play an important role in driving technological change and sustainable development. In the area of agricultural production it can also help ensure global food security (Patrício and Rieder, 2018). Across the entire supply chain system of the agri-food industry, artificial intelligence can solve the problem of information asymmetry in the food system, provide traceability of the entire food production process, from planting to consumption, contribute to the transparency of food production management and increase safety, as well as integrating the entire supply chain and greatly reducing transaction costs. In cultivation and production, AI technologies help to overcome the disadvantages of traditional technologies and detect and optimise the use of production materials, thus reducing waste. In addition, AI makes an outstanding contribution to the monitoring and control of carbon and biological footprints (Sanders *et al.*, 2021). The Barilla Pasta Factory has experienced a huge change in terms of improving food production and land and vegetation conservation and reducing energy consumption by creating decision support systems that collect, organise and process soil and weather data to provide farmers with timely information and advice (Stanco *et al.*, 2020). However, AI requires significant funding to develop the technology and associated hardware costs, which may entail a significant amount of money and create uncertainty about the future of the technology. At the same time, the impact of AI on society has been questioned. AI may fundamentally change the employment situation in the agricultural sector, replacing humans and thus impacting on the labour market (Sanders *et al.*, 2021). In addition, the development of AI tends to be uneven globally, with high-income countries having sufficient R&D funding to invest in and benefit from AI development, while low-income countries struggle to master the core technology. AI technology is therefore thought to exacerbate global equity issues and have an impact on the political landscape (Sparrow and Howard, 2021). Furthermore, the spread of AI may change the cultural patterns of traditional rural communities, thus posing a threat to social and mental health (Butler and Holloway, 2016).

4.1.2. *Process innovation in the cultivation stage*

The cultivation stage is one of the most important stages in the agri-food industry and the one with the greatest environmental impact. Considerable attention is paid to issues such as land conservation and the quality of agricultural products. SOI at the cultivation stage is integrated into planting, fertilisation, tillage, irrigation, weed control and pest control. Generally speaking, SOI at the cultivation stage is of great direct

benefit to the environment and can also bring significant financial benefits to farmers through improved productivity and quality. Awada and Phillips (2021) use an equilibrium displacement model to assess the profit-sharing consequences of technological innovations that improve the efficiency of land and other inputs in a multi-factor crop production system. They show that the adoption of land-technical innovations provides more lucrative returns to landowners than other technological innovations. However, agribusinesses, including farmers, are mostly small and medium-sized enterprises or farms (Dyck and Silvestre, 2019) with limited cost and risk-taking capacity. For example, in the case of climate-smart agriculture (transforming agri-food systems into green and climate-resilient systems), developers and users of technological innovations in the project have reported that the technologies are too expensive, have long pay-back periods and are not competitive in terms of ROI (Long *et al.*, 2017), so research on the costs of SOIs is necessary.

In the planting section, Yamoah *et al.* (2021) compare the practice of using the traditional no-shade method and the shade method in cocoa cultivation. The traditional no-shade method (full sun) ensures higher yields in the short term, but yields appear to be difficult to secure in the long term. The no-shade method also leads to negative environmental consequences such as deforestation, carbon loss, increased temperatures, depletion of soil nutrient levels, high inorganic fertiliser use, and loss of above- and below-ground biodiversity (Asare *et al.*, 2017). The shade method, on the other hand, although less productive in the short term than the no-shade method, provides more stable and sustainable cocoa productivity in the long term, and also reduces fertiliser use and pest and disease incidence. Kopytko (2019) summarises the advantages of sustainable seed innovations (both in situ conservation and innovation of new plant varieties through traditional practices). Financially, the innovation is less costly as it reduces the use of pesticides and fertilisers; environmentally, it ensures local ecological stability as the seed varieties are better suited to the local environment and the exchange of seeds between farmers maintains biogenetic diversity. Socially, the exchange of seeds between farmers creates a new social network, and the social status, professional competence and self-confidence of farmers are enhanced.

In the fertiliser application section, many technologies have been developed to replace conventional fertilizers. For example, Li *et al.* (2020) use manure to replace chemical fertilisers and discuss the effects of liquid and solid manure fertilisers separately. Compared to traditional chemical fertilisers, solid manure fertilisers reduce environmental impacts by 24.6% and increase profits by 17.2%, while liquid manure fertilisers are more effective, reducing environmental impacts by 37.9% and increasing profits by 19.1%. In addition to this, Fam and Mitchell (2013) use urine diversion technology to separate urine at source and recover nutrients for use in agriculture. All of these technologies can significantly reduce the environmental impact. However, the problem of high unit costs remains and it is not suitable for intensive production (Cappelli and Cini, 2021).

In the tillage section, Dyck and Silvestre (2019) conduct a study on the adoption of "conservation agriculture" by small-scale farms. "Conservation agriculture" refers to the protection of agricultural land by reducing mechanical disturbances, technical maintenance of the land during periods of downtime and crop rotation. "Conservation agriculture" doubles productivity in relation to financial benefits and reduces financial capital inputs. In terms of environmental benefits, conservation agriculture improves soil quality by facilitating access for the soil to carbon from the atmosphere. In terms of social benefits, "conservation agriculture" can improve the overall quality of life on small-scale farms and improve community health. However, Giller *et al.* (2009) point out that "conservation agriculture" suffers from erratic yields and may lead to increased labour demand, with the increased labour burden shifting to women.

In the irrigation section, drip irrigation technology is considered an important innovation in agriculture and offers a solution to the problem of water use. Dobbs *et al.* (2011) suggest that drip irrigation can reduce irrigation water use

by between 20% and 60% and increase yields by 15% to 30%. Drip irrigation combined with remote technology can reduce the manual labour associated with irrigation. Greenland *et al.* (2018) argue that drip irrigation technology has a high return on investment in terms of financial benefits and improves farmers' lifestyles in terms of social benefits. However, the equipment is more expensive to install, operate and maintain, and the maintenance and system management is more complex, requiring farmers to have more advanced technical skills.

In the weed control section, De Luca *et al.* (2018) study weed control techniques in olive cultivation. Within the three options: traditional control (involving chemical herbicides), low-dose/no-till (reduced chemical and mechanical use) and zero-chemical weed control (mechanical weed control only): the low-dose/no-till option performed best in the environmental dimension, with the lowest greenhouse gas emissions, ecotoxic emissions and land occupation; from the financial perspective, the low-dose/no-till option is the least costly, providing higher profitability and investment viability for the farm; in the social dimension, the zero-chemical weed control option does not use chemicals, providing greater profitability and investment viability for human health.

In the pest and disease control section, the search for natural alternatives to chemical agents is one of the main directions for SOI. To prevent the formation of caterpillars in crops, the SOI of parasitising a wasp called trichogramma on the eggs of pests has been proposed (Philippi *et al.*, 2015), where the number of applications is reduced from three to one compared to traditional insecticides. Biological control is also usually cheaper than the use of insecticides, thus reducing the cost of acquiring insecticides. The method also reduces local pollution as the spraying of insecticides easily infects people and non-agricultural areas. In terms of social benefits, it provides organic food for consumers and improves consumer health. Sellitto *et al.* (2021) studied the application of microbial biological control strategies in pest management. As an alternative to chemicals, biological control is beneficial in improving crop growth while indirectly reducing the fossil fuel and greenhouse gas emissions used in the chemical manufacturing process. Microbial-based biological tools can be useful in controlling plant diseases and simultaneously reduce contamination of agricultural products. Biological control tools can protect soil and plants before harvest and also after harvest by preventing crop spoilage and reducing waste. Gao *et al.* (2020) proposed the use of wheat straw vinegar, a natural fungicide obtained from the pyrolysis of wheat straw, as an alternative to chemical fungicides for the prevention of Fusarium head blotch, which not only improves fungicidal efficacy but also reduces the cost of fungicide to farmers and increases income.

4.1.3. *Process innovation in the production stage*

Cappelli and Cini (2021) argue that the use of innovative technologies in the wheat handling and product baking production process can both improve product quality and reduce energy and water consumption, which reduces the environmental impact. Cappelli *et al.* (2020d) study traditional stone milling flour technology. Stone milling technology retains more nutrients from the wheat, has a larger consumer market and, with some improvements in stone milling technology, can reduce energy consumption in the milling process, with potential benefits for the environment and production costs. In addition, there are some social benefits, such as improving the landscape and attractiveness of rural areas, thus improving the living environment for farmers; promoting the dissemination of traditional crafts, and thus promoting the transmission of traditional culture. Cappelli *et al.* (2020b) conduct a study on modern rolling mill technology. Rolling milling technology, as the most advanced wheat processing technology, has the advantages of high efficiency, flexibility and low heat generation, and does not affect the functional characteristics of the flour. With improvements in this technology, productivity can be increased and the environmental impact can be reduced through measures such as reuse of by-products and improved water utilisation. In the production of dough, the use of improved technology can increase environmental sustain-

ability (Cappelli and Cini, 2021). Cappelli *et al.* (2020a) investigate the use of snow carbonate as a refrigerant to control dough temperature during the kneading phase, a technology that is less costly and less energy intensive than low temperature retention technology. This technology has better cooling effects and does not contain the same level of chemical or toxic residues as other refrigerants, making it more environmentally efficient. Su *et al.* (2019) investigate the production of organic acids from by-products and waste substrates for use in the dough production process, which is effective in improving dough quality and reducing the environmental impact of by-products. In addition, Aljaafreh (2017) develops an intelligent process control machine for dough kneading, which introduces artificial intelligence into the production process, automates the production equipment and manual management, optimises all the technical specifications of dough kneading, reduces costs and reduces energy consumption and environmental impact.

Protein is the basis for human growth and health, yet the FAO estimates that approximately 1 billion people worldwide have inadequate protein intake. The shortage of protein supply has led to the search for alternative protein sources as an important issue in the production process. Plant foods (mainly cereals and legumes) account for 65% of human protein (Wu *et al.*, 2014) and are the main source of protein for humans. However, the extraction process suffers from inefficiency, waste and environmental impact, so it is necessary to develop more efficient and environmentally friendly plant protein extraction technologies to meet human nutritional needs as well as the requirements of sustainable development. Cappelli *et al.* (2020c) study the combination of chickpeas with cereals. The results show that the combination of chickpeas with cereals creates proteins of high biological value and can have a positive effect on environmental sustainability because chickpeas are grown using a smaller amount of nitrogen fertilisers. Soy protein is an available and relatively high-quality form of vegetable protein and to further improve the sustainability of soy protein production, a sustainable and innovative technology of concentrating and separating raw materials into individual components in the soy protein extraction process has been proposed. This allows the components to be recycled and reduces waste in the production process (Wu *et al.*, 2014).

4.1.4. *Process innovation in the distribution and consumption stage*

In the distribution stage, the adoption of digital technologies can play a role in logistics. Rana *et al.* (2021) suggest that various digital technologies such as barcodes/QR codes, RFID, IoT, ICT and blockchain can improve and simplify the traceability of food products across the supply chain while integrating these technologies can improve their functionality and reduce costs. In terms of blockchain technology, this allows participants in the supply chain to share data, quickly access relevant information and reduce costs (Rejeb and Rejeb, 2020). The technology also helps consumers track food sources, environmental impacts and ethical aspects (Saberi *et al.*, 2019). At the same time, the use of blockchain can help develop quantitative indicators related to sustainability and therefore contribute to a more sustainable agri-food industry (Rana *et al.*, 2021). However, blockchain technology requires a large amount of data to be collected and therefore involves significant funding. The blockchain network requires a lot of computing power, especially when it becomes complex, and therefore a lot of energy, implying an increase in costs and greenhouse gas emissions (Rana *et al.*, 2021).

At present, while there is a shortage of food in some parts of the world, there are also parts of the world where food is being wasted. At the consumption stage, food waste is a very serious problem, especially in hotels, restaurants and catering businesses that account for a significant share of total food waste. Not only does waste lead to inefficient food distribution, but the disposal of waste food also leads to the emission of harmful greenhouse gases. Statistics show that dealing with food waste accounts for 6% of the greenhouse emissions from the food industry (Poore and Nemecek, 2018). Therefore, how to reduce waste in the consumption chain

becomes an issue for sustainable development. Martin-Rios *et al.* (2021) examine sustainable solutions that use digitalisation and automation (especially artificial intelligence technologies) in this area, where companies integrate data network connections with waste handlers or build a device that measures the amount of food waste directly from the handling equipment and outputs data or reports directly to help managers develop waste prevention programmes. Such technology helps businesses to gain an insight into their food waste components, volumes, costs and sources, which is expected to lead to a 70% reduction in food waste and can significantly improve a restaurant's food profitability.

4.1.5. *Process innovation in the recycling stage*

Recycling refers to the creation of a regenerative system where waste, wastewater and other environmentally stressful by-products from the production processes (whether industrial or agricultural) are reused through technologies that slow, close and shrink material and energy cycles, minimising resource inputs and waste, emissions and energy leakage (Geissdoerfer *et al.*, 2017). For example, the "aquaponics" shore-based closed-loop production system combines plant cultivation (hydroponics) with fish production (aquaculture), using fish excrement to fertilise plants in the water, reducing stress on the link while providing nutrients for crop growth (Meisch and Stark, 2019). However, the circular economy must be accompanied by a shift in the social structure of the consumption and production system, so this system will be quite costly to establish (Gaudig *et al.*, 2021).

A large number of by-products and residues are generated during the food processing stage and such residues can cause great pressure on the environment, making the reprocessing and recycling of residues extremely important. Many relevant SOIs have been proposed, such as the example of producing organic acids from by-products and waste substrates and using them in dough production, as already mentioned above (Su *et al.*, 2019).

Biofuel technology is one of the more controversial technological innovations combining agriculture and industry. The use of food as biofuel to generate energy is a reality in a number of regions and such behaviour may exacerbate the threat to food security as well as the seizure of agricultural land (Raman and Mohr, 2014). In turn, the introduction of second-generation biofuel technologies using non-edible feedstocks has further contributed to sustainable development. For example, in Jordan and Israel, waste treatment through biogas units in the agricultural waste cycle segment has transformed agricultural waste into renewable energy (Pilloni *et al.*, 2020), avoiding the direct use of food for energy production. This is a good example of using biofuel technology while avoiding food waste. However, there are still potential social and environmental issues with biofuel technologies and Raman and Mohr (2014) argue that there is a spatial imbalance in biofuel technologies in that biofuel energy is not necessarily being produced where the real benefits are, and therefore may exacerbate global inequities. Fargione *et al.* (2008) suggest that the use of large amounts of agricultural land or non-agricultural ecological land such as rainforests for biofuel production could lead to higher food prices and indirectly increase greenhouse gas emissions.

4.2. *Product innovation*

According to the product life cycle involved in product innovation, product innovation is mainly concentrated in the cultivation, production, distribution and consumption stages, so only these three stages will be discussed in this section.

4.2.1. *Product innovation in the cultivation stage*

Currently, "retro-innovation" (designing new products, services and processes by combining past and present methods) for the cultivation of old wheat varieties is being adopted in order to find more health benefits in baked products (Cagliano *et al.*, 2016). This type of wheat produces more suitable nutrients, contributes to biodiversity conservation and simultaneously promotes sustained local microeconomic growth (De Boni *et al.*, 2019). However, older varieties suffer from poorer technical characteristics, with

poor dough rheology and smaller bread volumes compared to modern wheat varieties (Cagliano *et al.*, 2016). In addition, sorghum is seen as a product innovation in sustainable agriculture that can be widely used as a health and functional food to replace wheat in a specific range and provide healthier ingredients. Pontieri *et al.* (2022) summarise the characteristics of food-grade white sorghum as (1) low cost to grow, (2) high nutritional value, (3) gluten-free and, for specific consumers, an alternative to wheat, (4) rich in fibre and antioxidants, and (5) suitable for a variety of uses in the agri-food industry.

4.2.2. *Product innovation in the production chain*

Marotta *et al.* (2017) study the sustainability of the Rummo pasta factory, which has paid special attention to sustainability and public health, not only by reducing its environmental impact through sustainable technological innovations in the production process, but also by further proposing a sustainable and innovative product range aimed at improving consumer health, which has not only led to market success, gaining consumer acceptance and greater revenue, but has also improved the company's reputation, resulting in smoother contractual relationships with stakeholders and lower transaction costs. Combining product innovation with production technology innovation, the company has optimised its greenhouse gas emissions, energy use efficiency and production waste recycling, and has improved the quality of its employees' work at a social level, safeguarding their rights and increasing their productivity by making them much more productive.

4.2.3. *Product innovation in the distribution and consumption stage*

Exhibiting a "sustainable" label on commodities is an important product innovation in the consumption stage of the agri-food industry, with the aim of reducing the knowledge asymmetry in the distribution and consumption of sustainable products and increasing market recognition and sales of sustainable commodities. Currently, the more mature labelling systems include the sustainable label, organic label and fair-trade label. To obtain a label, companies need to be certified by a third-party organisation. Such certification provides producers with existing sustainable best practices and reduces the costs associated with producers finding and experimenting with these sustainable practices (Delmas and Gergaud, 2021). Also, because of the high authority and market acceptance of third-party labels, it helps to increase the willingness of consumers to pay a premium price and increases demand for the product (Heyes *et al.*, 2020). At the societal level, the economic benefits of labelling involve encouraging more producers to adopt sustainable practices, while labelling provides consumers with more information and guarantees about the product and increases public interest.

4.3. *Organisational innovation*

Most organisational innovations are made at the decision-making in TDS and system building stage of the company with the aim of improving unsustainability in multiple or even entire life cycle stages. Very few organisational innovations exist in isolation in a certain life cycle stage, so, in this section, the paper only contains a discussion of the enterprise decision-making in TDS and system building stage.

Innovations in technology play a prominent role in sustainable development, but are often affected by socio-economic barriers such as the inability of single technological instruments to address the integration of technological solutions and technology adoption (Sovacool *et al.*, 2015), and focusing only on technological innovation while ignoring the social and institutional dimensions may create new inequalities (Petruzzella *et al.*, 2020). Therefore, new approaches or systems are needed to understand the human dimensions and adoption of technology (Bale *et al.*, 2015). The adoption of innovative business models can facilitate the diffusion of technological innovations and increase their success by developing new value propositions, cost structures, profitability and ways of interacting with customers to address the problems of low initial profitability and uncertainty about the innovation (Long *et al.*, 2017). Adams *et al.* (2016) argue that the development of SOI requires three

shifts: from technology- or product-oriented innovation to human-centred innovation; from innovation in an independent sector of the firm to innovation that is widely integrated within the firm; and from innovation in isolation by a single firm to innovation in a system that is widely involved in social collaboration. The success of the urine diversion technology mentioned above (Fam and Mitchell, 2013) is not only due to its technical feasibility, but also to its human-centred social organisation, participation and integration of social knowledge from various stakeholders into the technology adoption process. Pilloni *et al.* (2020), through a socio-technical systems approach (combining technology with economics, ethics, philosophy, political science and sociological theories), summarise the successes and failures of biogas installations in Israel and proposes improvements at the social level (e.g., increasing the participation of women and community members) to generate greater social benefits while promoting the adoption and diffusion of biogas technologies.

The development and marketing of new products requires a lot of time, money and capacity. Therefore, SOI development is risky and usually requires a more collaborative and/or open systems approach (Chesbrough, 2010) since firms are able to solve these problems by collaborating and taking advantage of their partners. Collaboration not only removes some of the uncertainties inherent in SOI and reduces the riskiness of SOI, but also allows the configuration of the entire value chain to be adjusted (Cholez *et al.*, 2021). As a result, collaboration is generally considered to improve the ability of firms to engage in innovative activities (Pelse *et al.*, 2018). In response to this, the concept of open innovation was proposed. Open innovation can be seen as a new knowledge management model that involves an innovation process characterised by openness to the external world, challenging the more traditional closed innovation model that has been used by companies until now (Bigliardi and Filippelli, 2022). Lubell *et al.* (2011) demonstrate, in terms of the role of innovation and collaboration, that innovation can result in financial profits exceeding financial costs, while collaboration can enable social benefits to outweigh social costs. Interaction with third-party technology providers can facilitate a company's ability to innovate in SOI and reduce costs (Klewitz and Hansen, 2014).

Vecchio *et al.* (2020) argue that the creation of an innovation environment in which actors interact within a geographical area reduces innovation uncertainty and triggers innovation adoption, and that a systemic innovation environment is constructed with the joint participation of business, education and research, national institutional and legal frameworks, and finance (Pelse *et al.*, 2018). In the agri-food sector, the full participation of the farm and the interaction of all parties can contribute to the sustainability of the innovations adopted. As in the case of the Barilla pasta factory mentioned above (Stanco *et al.*, 2020), at each stage of the supply chain – agricultural stage, storage stage, production transformation stage and marketing stage – the company has established a "multi-stakeholder partnership", such as establishing agreements or ground rules with partners related to the commitment to sustainability at each stage. It has then established crop rotation systems among farmers for cooperation, which improves soil fertility, reduces costs and improves production efficiency and product quality while reducing market volatility and the financial risks associated with market volatility, providing long-term production security (Pancino *et al.*, 2019). Data show that the collective innovation led by Barilla has resulted in significant improvements in product quality, costs, farmers' income, resource consumption and waste emissions (Stanco *et al.*, 2020).

Collaboration in technology can drive the diffusion and use of SOI. Ponta *et al.* (2022) state that co-patenting can influence economic performance when firms develop SOIs, especially in the short term by reducing development costs, resulting in better economic performance. The Colombian National Federation of Rice Growers has improved sustainability through a large-scale technology transfer programme, resulting in a 23% increase in national average rice yields and a 26% reduction in average production costs (Orjuela-Garzon *et al.*, 2021). Technological collaboration between universities and industry can increase the innovation and technological

capacity of enterprises, while also leading to increased social benefits for all parties involved and society (Philippi *et al.*, 2015). Collaboration is made possible through technology transfer, where universities transfer their own developed technologies and knowledge to companies, bringing innovative capabilities and competitive advantages to them while promoting the adoption and diffusion of SOI. New business models of collaboration with research centres allow for lower costs in mass production, and government promotion can make collaboration on technology more successful and facilitate the realisation of expected and potential benefits (Philippi *et al.*, 2015). In the example above regarding AI technology to address food waste (Martin-Rios *et al.*, 2021), although the technology is thought to increase food profitability in restaurants, the restaurants' concerns about the cost of AI technology can affect SOI adoption as most restaurants are small and medium-sized businesses. However, by partnering with third-party technology companies, the restaurants can reduce the cost of technology adoption and reduce waste while not spending additional money. Schoenke *et al.* (2021) propose the concept of an AI and data streaming platform called Gaia-Ag-Stream, which is a platform for technology development and association that is collaborative in nature, bringing together research centres, industry, agricultural start-ups and farmers to help address the costs, knowledge gaps and technical deficiencies of SMEs in the AI rollout process, and to accelerate the adoption of AI. It will help solve the problems related to costs, the knowledge gap and technical deficiencies faced by SMEs in the process of AI diffusion and accelerate the adoption and diffusion of AI.

Innovations in investment and cooperation models can address the uncertainty and risk relating to the future of SOI technology and avoid future costs (Gaudig *et al.*, 2021). A number of scholars have contributed on innovation in investment and cooperation models: Seghieri *et al.* (2021) argue that a participatory approach involving public, private and civil stakeholders combined with a systematic and interdisciplinary approach is beneficial to promote the achievement of sustainable innovation. In order to improve food security in Africa, a large amount of aid such as funding and innovation programmes from Europe has entered African agriculture. However, it has not improved the situation much because it is fragmented between institutions, organisations and sectors, and between disciplines. Through stronger partnerships, especially between sectors and disciplines, the food security situation in Africa has improved, agroforestry landscapes have prospered and regenerated, farmers' poverty levels have been significantly reduced and Africa's out-migration trends have slowed (Seghieri *et al.*, 2021). Dyck and Silvestre (2019) examine the ways in which NGOs and farms or other organisations collaborate on sustainability innovations in the context of "conservation agriculture" practices, using small-scale farms in Nicaragua as a case study, comparing the use of traditional centralist approaches (where NGOs define standardised practices and farmers or other organisations adopt them directly) with new non-centric approaches (where NGOs adopt a more bottom-up, two-way approach to innovation, working with farmers and other organisations) in collaborative work. The findings suggest that non-centrism can address SOI uncertainty and promote SOI efficiency. Troise *et al.* (2021) argue that equity crowdfunding is a valuable way for open innovation to help agri-food companies pursue SOI so that agri-food companies do not use process-related crowd inputs when implementing SOI, and they also use knowledge-based inputs in organisational innovation to promote social sustainability. Long and Blok (2021) point out that the problem of inadequate innovation financing levels is a major barrier to addressing the climate situation, and that collaboration at the niche level, using the non-financial resources of existing actors to transcend asymmetries, can improve climate innovation performance.

4.4. *Discussion*

Process innovation and product innovation reflect technological upgrading and change, the main purpose of which is to optimise the production process and supply chain and reduce pollution by changing technology or finding al-

ternative products or raw materials, all in order to achieve both cost control in terms of financial benefits and sustainable development in terms of environmental benefits. At present, in the agri-food industry, there are three major directions of SOI in terms of technology and product types. Firstly, new technologies and products are being adopted at the planting stage to increase food production and nutritional content while reducing land pollution and resource waste; secondly, at the production stage, technologies and clean energy are being adopted to reduce the generation of waste gas, waste water and waste residue in the production process, or to recycle them; thirdly, in the process of supply chain operation and distribution, new technologies and products are being adopted to reduce waste and pollution in the distribution chain, and increase the transparency of distribution, so that product data can be collected in a timely manner, further analysed through digital technology and reduce waste.

At the planting stage, changes in planting technology have received a great deal of attention because human planting behaviour has a direct and profound impact on the environment. A great deal of SOI in the agri-food industry is focused on this segment and reducing chemical damage to the land and solving the problem of water scarcity have become hot topics. However, the high cost of adopting new technologies and the lack of guaranteed yields continue to hinder the spread of technology. The Mediterranean region has a population of more than 500 million people and a considerable economic imbalance within the region, with the northern and western parts of the region being highly developed and innovative, while the eastern and southern parts are densely populated and economically underdeveloped, facing not only pressure on the food supply but also limited innovation capacity. At the same time, the use of cultivation technologies in different regions can be greatly influenced by objective conditions (e.g. land conditions, hydrological conditions, climatic conditions, etc.), so there is a high degree of uncertainty about the effectiveness of new technologies in practice. Under the double threat of cost and yield uncertainty, it is difficult to popularise SOI in the cultivation segment. For example, in the case of water use, a large number of countries in the region are suffering from water stress, while on the other hand, it is difficult to promote the adoption of new irrigation technologies or water recycling systems due to their cost, which leads to a dilemma. Therefore, in the Mediterranean region, innovation in the cultivation sector requires further financial and food security guarantees to ensure that the process of sustainable development does not lead to a break in the food supply chain.

In terms of SOI adoption at the production stage, the ability of new technology to ensure or improve productivity and company profitability is a prerequisite for its widespread adoption. Agri-food production companies have higher cost tolerance and higher brand building requirements than growing farms, and therefore have a greater willingness and ability to be sustainable. Although the adoption of new technologies may mean a change of production equipment for the producer, the production capacity of the equipment is less affected by objective factors and has a higher yield stability and less technology adoption risk compared to new technologies in the planting stage. Therefore, the promotion of SOI adoption in the production phase requires the technology or product to have a high level of yield and stability and the lowest possible technology cost. In the Mediterranean region, where the capacity to develop production technologies is high due to the strong research capacity of the countries in the region, the problem is how to reduce the cost of adoption so that the technology can be more easily adopted.

In the supply chain, the increasing maturity of digital technology has provided strong support for transparency and process optimisation in the agri-food industry. The main forms of inter-organisational cooperation include horizontal, vertical and multi-stakeholder cooperation, with digitisation being considered a horizontal trend in all types of cooperation (Cholez *et al.*, 2021). However, digitisation of the supply chain is a system-wide issue, and digitisation by a single player in isolation makes it difficult to optimise the supply chain and can lead to higher operational costs for companies. At the same time, the new resource waste and pollution (e.g., resource

consumption and gas emissions from large-scale computing), cybersecurity and moral risks associated with large-scale digital operations have not been fully practiced and proven, so digitisation faces huge unknown costs. In the agri-food sector in particular, there is a potentially significant risk that the information gap between companies may lead to a "digital divide" and further polarisation between rich and poor. In order to ensure a more equitable and inclusive digitisation of agriculture, farmers need to be further motivated to adopt digital technologies through the role of social influence and improved organisational conditions (Giua *et al.*, 2022).

SOI at the organisational level, especially SOI based on cooperation, can complement and enhance SOI at the technical and product levels. A multi-stakeholder partnership leverages each other's resources and complements each other's shortcomings. Resources are the motivation for cooperation, including internal resources such as entrepreneurship, finance and know-how, and external resources such as external services, market intelligence and public funding (Camanzi and Giua, 2020). Different stakeholders have different roles to play in cooperation and constitute different types of cooperation with each other. Producers (or farmers) are both developers and end-users of SOI technologies throughout the supply chain, and cooperation between individuals is based on technology and knowledge. Technology transfer cooperation, for example, enables innovative technologies to be better disseminated within the industry, reduces the costs and inputs for the introduction of relevant technologies by companies in the industry, and reduces the financial pressure for sustainable development. Another subject of technology-based cooperation is third-party technology companies, which authorise the use of developed technologies to production entities, or production entities outsource technology development to third-party companies, in such a way that reduces the R&D costs and technology risks of production entities. Third party companies are able to leverage their talent by bringing together R&D talent to focus on technology development and consequently improve the technological level and sustainability of the entire supply chain. Funding-based collaborations involve public, private and stakeholder parties. Through investment, the cost of developing and using SOI technology in companies can be addressed, reducing the financial pressure for sustainable development. The issue of investment efficiency is a noteworthy aspect of financial cooperation, which can be effectively improved through the adaptation of public policies and investment cooperation models, thus improving sustainable performance.

Overall, collaboration is one way to effectively improve the sustainability level of the industry. However, the depth and breadth of cooperation can be deepened and expanded. Regions with backward economic development may face the problems of a shortage of funds for technology research and development, a poor production environment due to the quality of the population and a lack of research professionals. The capacity of the backward regions is also needed. Especially in the Mediterranean region, where regional development is highly uneven, more optimisation at the organisational level is needed. On the one hand, in the more developed northern and western regions, there is a need for increased cooperation, especially on a financial basis, to stimulate initiatives of producers or third-party companies to develop SOI technologies. On the other hand, in the less developed southern and eastern regions, the dissemination and diffusion of existing SOI technologies is a major challenge, and therefore technology-based and public service cooperation needs to be deepened and optimised.

5. Conclusions

SOI adoption is restricted due to its cost and the uncertainty about its benefits. This paper provides an overview of the costs and benefits of specific SOIs in the agri-food industry, summarising the costs and benefits of different types of SOI at the different stages. Both process and product innovations are aimed at producing environmental and social benefits, but generating more financial benefits requires organisational innovation to further "innovate for innovation". Organisational innovation can be seen as

a complement to process and product innovation and plays a key role in the diffusion and adoption of SOI. Summarising the dimension of the agri-food production cycle, the cultivation and production stages are the most stressful for the environment and therefore a large number of SOIs are focused on these two stages, aiming to guarantee or even increase production while reducing the pressure on the environment. The organisation and system building stage, as a cornerstone, guides the direction of the company on sustainability issues and offers a guarantee for SOIs in other life cycle stages.

As the Mediterranean region has a low propensity to innovate, this review provides guidance on the adoption of innovation in that region, especially for small and medium-sized agri-food companies based there, to help them judge the costs and benefits of SOI when adopting it. In relation to inter-industry cooperation, this paper summarises potential opportunities and ways to collaborate and contribute to improving inter-industry cooperation on sustainability issues. For policy makers and regulators, there is a need to understand the potential costs and risks of different types of SOI and the barriers for companies to develop and use the technology when developing relevant policies to support sustainable development. When policies are developed in isolation from the realities of SOI technology, they can be less effective. The information provided in this paper on the different types of SOI technologies therefore provides them with a direction for policy development, and the SOI at the organisational level provided in this paper helps to advance the continuous innovation and deepening of policies that can stimulate large-scale sustainable industry transformation. For the academic community, the SOI classification framework presented in this paper can be used for future research.

However, since the query terms were not the most extensive when searching the database and there is an excess of literature on specific technologies, it is difficult to include them all in the review. Therefore, there is still a large amount of relevant literature that is not included in the scope of the review, and a large amount of information is ignored as a result. At the same time, the costs and benefits of specific SOIs are not static since they change as technology advances and society evolves. In particular, for technological innovations that generate environmental benefits, the awareness of their potential risks and potential negative impacts on the environment is limited by the current level of human cognition and will only be gradually exposed as that increases.

Finally, the SOIs studied in this paper are designed to reduce the pressure on the environment and society and to slow down environmental and social degradation. Recently, however, the concept of "Sustainability 2.0" has emerged, which aims not only to mitigate environmental and social problems but also to improve our current environment and society. Therefore, based on this paper, future research could take the concept of "sustainability 1.0" to the level of "sustainability 2.0" and conduct more in-depth research.

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Nutritional information as a source of consumer power and psychological empowerment

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Abstract

The aim of this research is to determine the extent to which the use of the Internet and web technologies can enhance consumer power and psychological empowerment. Based on theories of power and empowerment, a model is proposed to improve the understanding of consumers' attitudes towards their food choices. The results show that the model tested among 300 Moroccan consumers using the structural equation method PLS explains a positive and direct effect between the use of the Internet and web technologies and the power of consumers in terms of food, and consequently their psychological empowerment in their food decision-making.

***Keywords**: Internet, Web technology, Power, Psychological empowerment, Food.*

1. Introduction

In the context of the producer-consumer relationship, the use of the Internet and the development of connected objects, social media, and nutrition applications promote the effect of consumer empowerment (Pires *et al.*, 2006; DiFilippo *et al.*, 2015). These technologies give consumers easy access to a lot of information about food, its composition, and its origin (Adamski *et al.*, 2020). Consumers can also compare prices, opinions of other consumers, and nutritional information by having direct access to a wide range of alternatives (Davies and Elliott, 2006).

In addition, the boom of social media and nutrition apps has greatly expanded the scope of consumer information about food and contributed to the emergence of new practices of sharing culinary and nutritional information that has led to changes in attitudes, behaviors and food culture (Lee *et al.*, 2014).

These new forms of interaction promote the creation and sharing of information within virtual networks and communities, and therefore strengthen the power of consumers in their relationships with brands (Labrecque *et al.*, 2013).

According to several researchers (Wathieu *et al.*, 2002; Harrison *et al.*, 2006), the rise of technology and the Internet has given consumers more control over their purchasing and consumption decisions. This shift in power has resulted in the transformation of the balance of power in favour of consumers (Kucuk and Krishnamurthy, 2007).

Thanks to the information provided by digital devices, consumers no longer accept the role of

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passive consumers but are increasingly empowered and seek equal relationships with brands (Rual, 2019). They are no longer passive consumers who are unaware of their consumption; instead, they want to play an active role in their consumption and dietary choices, and they have become "consum-actors" or more precisely, "empowered" consumers (Fayn *et al.*, 2019).

Therefore, consumer empowerment in food refers to the process by which consumers acquire the knowledge, skills and tools to make wise and autonomous food choices that empower them in their decision-making process (Nam, 2019).

This study aims to answer the following research question: To what extent does the use of Internet and web technologies influence consumers' power over food and their psychological empowerment in food choices? To answer this question, we propose the following plan: a literature review that includes the main theories related to the research question, then a research methodology appropriate to the research question, data analysis, discussion of the results, and finally theoretical and economic implications, accompanied by limitations and new research avenues.

2. Literature review

2.1. *Internet use and the psychological empowerment of consumers*

Rappaport and Zimmerman's empowerment theory is a theoretical model that focuses on the process by which individuals and communities gain and retain power, control and influence over their lives and environments (Rappaport, 1987; Zimmerman, 1995). This theory is introduced to examine the impact of the use of the Internet and web technologies on consumers' power over food and thus on their psychological empowerment in making food decisions.

In marketing, the concept of consumer empowerment accompanies the rise of the Internet: it refers to the consumer's gain in skills, autonomy, and control (Wathieu *et al.*, 2002; Davies and Elliott, 2006). Some authors see empowerment as a psychological state of gaining power through the use of the Internet (Wright *et al.*, 2006; Davies and Elliott, 2006). Other authors, however, see empowerment as a process of delegation of power that is voluntarily initiated by a company in the context of co-creation activities (Füller *et al.*, 2009). Both concepts, psychological empowerment on one hand, and empowerment strategy on the other, share the idea of gaining skills, but differ greatly in their scope of application (Pruche, 2015). Therefore, empowerment can arise from the customer's initiative in using digital technology, but also from the actions of brands and other actors (Cases, 2017).

The approach used in this study is referred to as the "psychological approach," which focuses on the extent to which individuals or consumers actually experience a sense of empowerment based on their individual perceptions of self-awareness, self-determination, and self-efficacy in their food decision-making (Ben Ayed and El Aoud, 2016).

Referring to the conceptualization of (Ben Ayed and El Aoud, 2016), psychological empowerment of the consumer in the domain of food is associated with three dimensions:

Self-awareness: This refers to the consumer's ability to be aware of their food preferences, beliefs and values (Ben Ayed and El Aoud, 2016). This ability enables the consumer to better understand their food choices and make more conscious decisions (Nam, 2019).

Self-determination: This refers to the consumer's ability to make autonomous food choices based on their own values and preferences (Ben Ayed and El Aoud, 2016). This ability allows consumers to take control of their food choices and feel more confident in their decisions (Nam, 2019).

Self-efficacy: This refers to the consumer's ability to apply their knowledge and skills in relation to food, as well as their ability to deal with the obstacles and challenges they may encounter (Ben Ayed and El Aoud, 2016). This competence enables the consumer to feel competent and capable of making healthy food choices and maintaining healthy eating behavior in the long term (Nam, 2019).

According to Pitt *et al.* (2002); Davies and Elliott (2006), the use of the Internet and digital technology is the most important source of consumer empowerment. Indeed, the literature review revealed that the idea that the use of the

Internet and web technology has an "empowering effect" on consumers has long been held in the literature, especially since the introduction of the Internet in the 1990s (Pitt *et al.*, 2002; Davies and Elliott, 2006; Harrison *et al.*, 2006; Kucuk and Krishnamurthy, 2007). In general, empowered consumers are able to make appropriate choices from a range of goods and/or services (Harrison *et al.*, 2006). A consumer who uses the Internet to learn about the nutritional values of the products he consumes contributes to the development of a sense of individual or psychological empowerment (Wright *et al.*, 2006). This developed competence makes the consumer more autonomous in his decision-making process (Pruche, 2015).

As confirmed by (Nam, 2019), consumer empowerment in the food sector is a process that enables consumers to make more informed and autonomous decisions about their food choices. Indeed, the Internet has long been seen by various experts as one of the ways in which individuals can take responsibility for their health (Lemire *et al.*, 2007; Hardey, 2001).

Some authors believe that the use of the Internet would encourage users to take responsibility for their own health through their food choices (Hardey, 2001). This technological use can encourage consumers to adopt healthier food choices and take measures to prevent chronic diet-related diseases through direct access to a wide range of health and nutrition information provided by the Internet (Banti *et al.*, 2016). Consequently, this empowerment effect reinforced by successive developments in digital technologies (Labrecque *et al.*, 2013) gives rise to a self-aware consumer in his consumption, self-effective in his choices, and self-determined in his food decisions (Nam, 2019; Ben Ayed and El Aoud, 2016). A strong relationship is therefore observed between the use of the Internet and web technologies and the psychological empowerment of consumers in their food decision-making. Hence, the following hypothesis is retained:

H1: The use of the Internet and web technology positively impacts the psychological empowerment of consumers in their food decision-making.

2.2. *The use of the Internet and the power of the consumer*

The focus has been placed on French *et al.*'s (1959) theory of sources of power to understand the antecedents of psychological empowerment. This theoretical framework is particularly fundamental to clearly understand the impact of the Internet and web technologies on consumer power. The theory has been used several times in conceptual work in marketing to assess consumer (perceived) power (Rucker and Galinsky, 2008), specifically in the context of purchase decisions (Rezabakhsh *et al.*, 2006).

Indeed, some authors explicitly rely on the power theory of (French *et al.*, 1959) to justify the thesis that the use of the Internet would favor a gain in consumer power (Rezabakhsh *et al.*, 2006; Moati, 2009).

French *et al.* (1959) identified five sources of power: reward power, coercive power, legitimate power, referent power, and finally, expert power. The theory of power sources by French *et al.* (1959) has been put into practice in marketing to particularly clarify the impact of the Internet and web technologies on the power of the consumers in their purchasing decisions (Harrison *et al.*, 2006). Three sources of power are appropriate for explaining consumer power in the sphere of commercial relationships, starting with expert power, followed by voice power (including reward power and coercive power) and finally legitimate power (Pruche, 2015). This study focuses on three sources of power (French *et al.*, 1959) perceived through the use of the Internet and web technology in the context of a purchase decision (Rezabakhsh *et al.*, 2006).

The power of expertise is a power derived from a person's knowledge or expertise in a particular field (French *et al.*, 1959). It refers to an individual's ability to influence others due to their knowledge or expertise in a particular field and varies depending on the degree of expertise that P attributes to O in a given domain (Pruche, 2015).

Pitt *et al.* (2002) have shown that the use of the Internet and web technologies would in-

crease consumer power by helping to reduce information asymmetry in market relations between producers and consumers.

In the context of food, consumer expert power refers to the consumer's ability to use available online information to make informed food decisions (Banti *et al.*, 2016). Consumers can access a large amount of information online, including product reviews and nutritional evaluations (Pollard *et al.*, 2015). By using this information, consumers can become experts in their own food choices, able to select the foods that best fit their dietary needs and preferences (Nam, 2019).

As (Li *et al.*, 2022) confirmed, consumers today have a growing food expertise, and are increasingly aware of food safety issues, sustainability and the environmental impact of food production, and expect food products to meet these criteria.

As noted by (Rezabakhsh *et al.*, 2006), before the Internet, consumers lacked 'expert power' due to information asymmetries since brands deliberately withheld information. However, web technologies have enabled consumers to search and compare nutritional information on different foods, allowing them to make more rational food choices (Pires *et al.*, 2006). The spread of the Internet has helped to reduce information asymmetries and improve market transparency for consumers (Grewal *et al.*, 2003). Therefore, the following hypothesis, which posits a strong relationship between Internet use and expert power in the field of food information, is retained:

H1a: The use of the Internet and web technology positively impacts consumers' expertise power over food.

The power of the voice, which includes both reward and coercive power, is strengthened by the Internet (Pruch, 2015). This is because it allows communication and dissemination of positive and/or negative opinions to a wider audience, as well as the ability to reward or punish a brand (Labrecque *et al.*, 2013).

The power of reward refers to one person's ability to reward another for their actions or behavior (French *et al.*, 1959). In the context of food brands, consumers can exercise their power of reward by purchasing products from a particular brand via electronic word-of-mouth on the Internet (eBAO) (Hennig-Thurau *et al.*, 2004). However, the digital age has provided consumers with unprecedented access to nutrition information, enabling them to develop their relational skills by sharing their opinions and preferences with other consumers (Pruch, 2015).

Coercive power is the ability of a person to punish in order to achieve a desired behavior (French *et al.*, 1959). In the context of the brand-consumer relationship, consumers can exercise their power by choosing not to buy a product (coercive power), using their expertise to evaluate the quality of that product (expert power) (Pruche, 2015). Thus, if consumers are satisfied with the product quality of a food brand, they may decide to reward it by buying more products from that brand. If, on the other hand, consumers are dissatisfied with the quality of that food brand, they may decide not to buy more products from that brand (Hirschman, 1970).

As a result, through the opportunities offered by these technologies, consumers may reward or sanction the brand by accepting a loyalty reward and/or negative sanctions such as 'exit' and 'voice' (Hirschman, 1970). Therefore, a strong relationship is observed between Internet use and consumer voice. Hence, the following hypothesis is proposed:

H1b: Internet use and web technology have a positive impact on consumer voice in food.

Legitimate power is the power derived from a person's status or hierarchical position (French *et al.*, 1959). The Internet would give legitimate power to the customer by challenging the traditional division of roles within the business relationship between producer and consumer (Moati, 2009).

The producer traditionally determines the characteristics of the product and is perceived as legitimate for doing so (Pruche, 2015). The consumer's decisions are mainly about whether or not to buy the product, but not about the definition of the product itself (Hirschman, 1970). However, with the advent of the Internet, consumers can participate in the co-creation of products with brands, reversing the

balance of power between brands and consumers and rebalancing exchange relationships (Fayn *et al.*, 2019). This collaborative approach allows brands to have an open dialogue with consumers about food ingredients (Belharar and Chakor, 2022) and involve their customers or consumers more in the product development process, while giving consumers a sense of involvement and satisfaction in their shopping experience (Fernandes and Remelhe, 2016).

The brand « c'est qui le patron ? » is an example of empowerment campaigns that involve consumers in the development of healthy, responsible and ethical products and give them a sense of participation (Renault, 2019).

Consumers can influence the practices of food brands by exercising their decision-making power through information available online and helping to promote more sustainable and ethical practices in the food sector (Levkoe and Blay-Palmer, 2018). By exerting social pressure on brands, consumers can promote more sustainable and ethical practices that respect farmers and animals and ensure transparency of ingredients and production methods (Sen and Bhattacharya, 2001). There is thus a strong link between Internet use and consumers' legitimate power over food. This leads to the following hypothesis:

H1c: Internet use and web technology have a positive impact on consumers' legitimate power over food.

Consequently, empowering consumers in terms of their expertise, voice and legitimacy can help them to have a greater say in food decisions, i.e. make healthy food choices and improve public health in general (Wang *et al.*, 2020). These authors argue that feelings of power can influence food choices in two ways: by influencing perceptions of the relevance of food choices and by influencing perceptions of the ability to make healthy food choices, i.e. a psychological state of empowerment in food decisions (Wang *et al.*, 2020).

These three sources of perceived power through the use of the Internet and web technologies promote, thus the emergence of an "empowered" consumer (Pruche, 2015). Similarly, consumers' power over food contributes to their psychological empowerment and their ability to make rational decisions that can influence their perception of food risks and their satisfaction with their food consumption (Nam, 2019).

As Pruche (2015) notes, variation in any of these three sources of power – expert power, voice power and legitimate power – should lead to variation in the same direction of the consumer's perceived sense of power or psychological empowerment. In relation to this topic, variations in each of these three sources of power – expert power, voice power and consumer legitimate power in relation to food – should lead to variation in the same direction of consumers' perceived sense of power or psychological empowerment in their decisions about food (Pruche, 2015). In other words, expert power, voice power and consumers' legitimate power in relation to food are antecedents to consumers' psychological empowerment in food decisions, according to (Pruche, 2015; Nam, 2019; Wang *et al.*, 2020). Thus, a positive relationship is found between expert power, voice power and legitimate power in food issues and the general psychological empowerment of consumers in their food choices. Therefore, the following hypotheses are retained:

H1d: The expert power of consumers in food matters positively impacts their psychological empowerment in their food choices.

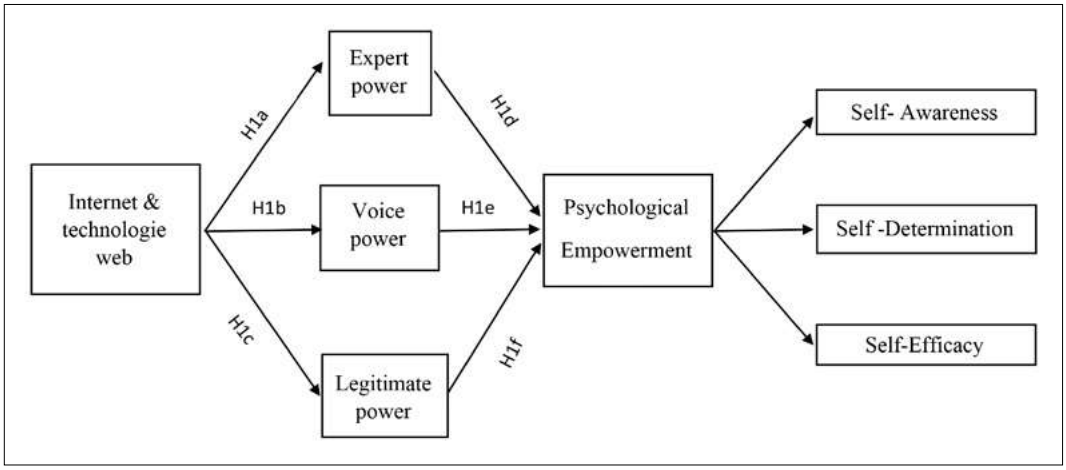
H1e: The voice power of consumers in food matters positively impacts their psychological empowerment in their food choices.

H1f: The legitimate power of consumers in food matters positively impacts their psychological empowerment in their food choices.

2.3. *Aim and hypothesis*

The aim of this article is to answer the following research question: To what extent does the use of the Internet and web technologies influences consumers' power over food and, consequently, their psychological empowerment in food choices? The results of the literature review have made it possible to create

Figure 1 - Theoretical model.



a conceptual model with all the research hypotheses, which is shown in Figure 1.

3. Research methodology

The authors aim to evaluate how the Internet and web technologies impact consumers' power over food and their psychological empowerment in food choices. They collect data using a quantitative approach and a questionnaire, following Thiétart's (2007) method for data collection. Using the Google Form platform, they collect questionnaires over three months (May-July 2021). Results are obtained by testing a series of hypotheses based on a conceptual model derived from the literature review.

3.1. *The participants*

The selection of participants was carried out through convenience sampling, which involves selecting participants based on their availability, accessibility, or willingness to participate in the survey. The sample size for this study is calculated using the Cochran formula, as this formula is often used when using convenience sampling to minimize sampling errors and biases in survey results.

Therefore, the sample size is calculated based on the following data: a confidence level (z) of 1.96, an estimated proportion (p) of 0.5, and a tolerated margin of error (e) of 0.06.

$$n = \frac{z^2 pq}{e^2} = \frac{1.96^2 * 0.5(1-0.5)}{0.06^2} = 267\ person$$

The study sample includes 300 Moroccan participants, which exceeds the minimum number required.

3.2. *Operationalisation of variables*

The model variables include a dichotomous variable and continuous variables. A dichotomous measure (yes or no) was used to measure Internet and web technology use, and a five-point Likert scale was used to measure the continuous variables of the research model (Annexe 1).

The power variable consists of three power variables – expert power, voice power, and legitimate power. These were developed by French *et al.* (1959) and Swasy (1979) based on the theory of sources of power. Each variable is composed of several items. Expert power has three items, voice power has three items, and legitimate power has two items. The items used in a study of food purchasing decisions were adapted from those used by (Pruche, 2015) in a study of travel purchasing decisions.

The psychological empowerment variable: authors (Ben Ayed and El Aoud, 2016) proposed a scale to measure the psychological empowerment of health-conscious patients, which was adapted for this study because its dimensions seem relevant to consumers who have become

health-conscious through their diet. Psychological empowerment includes three dimensions: self-awareness, self-determination, and self-efficacy, each measured by 5 items (self-awareness), 3 items (self-determination), and 4 items (self-efficacy). Spreitzer (1995) has theoretically confirmed the existence of a second-order factor (empowerment) composed of these three first-order factors, but this still needs to be statistically confirmed by a confirmatory factor analysis.

3.3. *Data analysis*

The authors analysed the demographic profiles of the respondents using descriptive statistics. Since their research model contained 6 continuous variables, namely: expert power, voice power, legitimacy power, self-awareness, self-determination and self-efficacy, they used principal component analysis (PCA) to reduce dimensionality, identify important variables, detect relationships between variables, and strengthen Ben Ayed and El Aoud's (2016) measurement scale. They then conducted confirmatory factor analysis (CFA) to test the research model and assess relationships between variables.

The authors tested their model using the PLS-SEM method and evaluated the measurement and structural models using various indices. They also analyzed the demographic profiles of the respondents, reduced the data with SPSS v23, and evaluated the external measurement and internal structural models using SMARTPLS.

4. Descriptive statistics

Demographic profile of respondents

Of the 300 respondents, 85 were men (32.7%) and 215 were women (67.3%) whose ages ranged from 18 to over 65, with the majority between 25 and 35. In terms of occupation, 35% of respondents were students, 22.3% were employees, 24% were civil servants, 7% were entrepreneurs and 4.3% were self-employed. Regarding income, 34% of the respondents had no salary, while the remaining 62% had an income ranging from less than 5000 DH to over 30000 DH. The majority of respondents have an educational level ranging from bachelor's degree to doctorate. In addition, 94% of the respondents said that they checked the nutritional values on the Internet before buying a food product, while 5% did not (Table 1).

Table 1 - Demographic profile of respondents.

The use of the Internet to search for information		
Internet use	*Frequency*	*Pourcentage*
Yes	285	95%
No	15	5%
Total	300	100%
Percentage of consumers by gender		
Female	215	67.3%
Male	85	32.7%
Total	300	100%
Socio-professional category of consumers		
Student	105	35%
Employee	67	22.3%
A civil servent	72	24%
Entrepreneur	21	7%
Self-employed	13	4.3%
Other	22	17.3%
Total	300	100%
Consumers' income		
No salary	102	34%
Less than 5000DH	31	10.3%
5000-10000 DH	64	21.3%
10000-20000 DH	51	17%
20000-30000 DH	16	5.3%
More than 30,000 DH	24	8%
Total respondents	288	96%
No response	12	4%
Total	300	100%
Age		
Less than 25 years old	94	31,3
25-35 years old	95	31,7
46 -55 years old	72	24,0
56-65 years old	32	10,7
More than 65 years old	7	2,3
Total	300	100,0
Level of education		
Bachelor's degree	16	5,3
2-year university degree	56	18,7
3 or 4-year university degree	90	30,0
5-year university degree	100	33,3
8-year university degree	38	12,7
Total	300	100,0

Source: data (SPSS output).

Table 2 - Principal component analysis.

Measured variables	*Scales used*	*Items*	*Number of items retained*	*Relative contribution*	*The total variance explained*	*Alpha Cronbach*
Expert power (EP)	French *et al.*, 1959; Swasy, 1979; Pruche, 2015	*EP1*: I am better positioned to make a good choice among the available food offers	3	0.864	71.990	0.804
		EP2: I have all the information I need to make an informed purchase		0.855		
		EP3: I feel capable of choosing my consumption.		0.825		
Voice power (VP)	French *et al.*, 1959; Swasy, 1979; Pruche, 2015	*VP1*: It has become easy for me to share reviews with consumers	2	0.882	77.751	0.714
		VP2: I know that I can raise my voice whether I am satisfied with my consumption or not		0.882		
		VP3: The opinion of the consumer has become important for the producer		0.675		
Legitimate power (LP)	French *et al.*, 1959; Swasy, 1979; Pruche, 2015	*LP1*: I can influence consumers through the products I consume	2	0.850	72.245	0.610
		LP2: I have the ability to adjust the ingredients of the product if the brand allows it.		0.850		
Self-Awareness (Awars)	Ben Ayed & El Aoud, 2016)	*Awars1*: I think I am the person who knows best about his or her health status and needs	5	0.752	60.685	0.838
		Awars2: I am aware of situations and experiences that can have a negative influence on my decisions		0.785		
		Awars3: I know where to find information to take care of my consumption		0.785		
		Awars4: I know how to take care of my health by being mindful of what I consume.		0.775		
		Awars5: I am very concerned about my health: (choice of food, products, their composition, etc.)		0.797		
Self-Determination (Det)	Ben Ayed & El Aoud, 2016	*Det1*: I have control over myself and know what is good for my health	3	0.894	76.430	0.846
		Det2: I show independence and responsibility for myself.		0.886		
		Det3: I can choose healthy eating goals		0.842		
Self-Efficacy (EffI)	Ben Ayed & El Aoud, 2016	*Effi1*: I can choose my consumption according to my nutritional goals	4	0.802	66.634	0.831
		Effi2: I am able to understand the difficulties that arise in my consumption decisions		0.800		
		Effi3: I am able to decide which way is the best for me to reach my nutritional goals		0.847		
		Effi4: I believe that I can sustain a long-term dietary change		0.815		

Source: data (SPSS output).

5. Principal component analysis (PCA)

The results in Table 2 indicate that for all research model variables (expert power, legitimate power, self-awareness, self-determination, and self-efficacy), the relative contribution is higher than the norm (0.7) for the majority of items. The information retained after Varimax rotation exceeds the norm, which recommends a value greater than 50%. In terms of construct reliability, the Cronbach's alpha coefficient is also higher than the norm, which recommends a value greater than 0.7, or even 0.6. With the exception of the third item "Voice Power," which lacks sufficient representativeness, all other items are retained. This exclusion improves the analysis efficiency.

6. Confirmatory analysis (CFA)

6.1. *The measurement model*

Internal consistency reliability

Internal consistency reliability is assessed using two criteria: Cronbach's alpha and composite reliability (Chin, 1998). These values generally range from 0 to 1. Values that are often considered to indicate a good level of reliability are 0.7 (Tenenhaus *et al.*, 2005).

In general, the results collected in Table 3 show that the criteria required to ensure the reliability of the internal consistency of all variables in the measurement model are met according to the evaluation criteria used in the literature.

Convergent validity

Convergent validity relies on examining and evaluating the correlations between indicators and their latent variable, as well as the average variance extracted. To be considered valid, a measurement scale must have correlation coefficients greater than 0.7 (which assumes that the latent variable shares more variation with its indicators than error variance) (Fernandes, 2012) and an AVE greater than 0.50 (Fornell and Larcker, 1981).

The results in Table 4 indicate that all items composing the variables in the model have factor contributions above the recommended threshold of 0.7 (Fernandes, 2012). Additionally, the examination of the average variance extracted from all variables shows a value above the recommended threshold of 0.5 (Fornell and Larcker, 1981). Therefore, the results demonstrate that the criteria for ensuring convergent validity of the measures associated with the constructs have been met, as assessed by factor contributions and average variance extracted.

The results of Table 5 for the second-order variable 'psychological empowerment' are significant, as indicated by the Cronbach's alpha value of 0.844, which is higher than the recommended norm of >0.7, the composite reliability value of 0.883, which is also higher than the norm of >0.7, and an AVE value of 0.520, which exceeds the norm of >=0.5. In fact, the loadings of the first-order latent variables on those of the second order (empowerment) are all >0.5 and significant. Therefore, the second-order model

Table 3 - Internal consistency reliability.

Variables	*Alpha de Cronbach*	*P-value*	*Criteria*	*Results*	*Composite reliability*	*P-value*	*Criteria*	*Results*
Expert power	0.805	0.000	> 0.7	Reliable	0.885	0.000	> 0.7	Reliable
Voice power	0.616	0.000			0.838	0.000		
Legitimate power	0.714	0.000			0.875	0.000		
Self-Awareness	0.838	0.000			0.885	0.000		
Self-Dermination	0.845	0.000			0.907	0.000		
Self-Efficay	0.833	0.000			0.888	0.000		

Source: data (SMART PLS outputs).

Table 4 - Convergent validity.

Variables	*Outer Loading*	*Criteria*	*AVE*	*Criteria*
EP1 <=EP	0.864	>0.7	0.720	>=0.5
EP1<=Empowerment	0.774			
EP2 <- EP	0.855			
EP2 <- Empowerment	0.788			
EP3 <- EP	0.826			
EP3 <- Empowerment	0.748			
LP1 <-=LP	0.877			
LP1<=Empowerment	0.702			
LP2 <=LP	0.820		0.721	
LP2 <=Empowerment	0.820			
VP1 <=Empowerment	0.727		0.777	
VP2 <=Empowerment	0.701			
VP1 <= VP	0.887			
VP2 <=VP	0.876			
Awars1<= Self-Awareness	0.750		0.606	
Awars2<= Self-Awareness	0.778			
Awars3<= Self-Awareness	0.804			
Awars4 <= Self-Awareness	0.769			
Awars5<=Self- Awareness	0.790			
Det1 <= Self-Determination	0.891			
Det2 <= Self –Determination	0.882		0.764	
Det3<=Self-Determination	0.849			
Effi1 <= Self-Efficacy	0.800			
Effi2 <=Self- Efficacy	0.792			
Effi3 <=Self- Efficacy	0.839		0.666	
Effi4 <=Self-Efficacy	0.831			

Source: data (SMART PLS outputs).

Table 5 - Convergent validity and internal consistency reliability of the second-order structure of the empowerment variable.

Variables		*Convergent validity*	*Reliability*	
Variable of order 2	*Variable of order 1*	*AVE*	*Alpha cronbach*	*Composite reability*
Empowerment	Self-awarness	0.520	0.844	0.883
	Self dermination			
	Self-efficacy			

Source: data (SMART PLS outputs).

of empowerment fits the data well. Thus, the second-order construct of psychological empowerment, as well as its reliability and convergent validity, are confirmed.

Discriminant validity

Two tests to assess the discriminant validity of a construct, namely the discriminant validity test of Fornell and Larcker (1981) and the discriminant validity test of Lacroux (2009). The first test uses the average variance extracted (AVE) to measure the variance shared between a construct and its measured variables, while the second test uses the cross-loading test to test whether the indicators measuring a latent variable are more strongly correlated with that variable than with the other latent variables in the model.

The results of the Tables 6-7 of the discriminant validity test show that the criteria for establishing discriminant validity (assessed by examining the correlations between the constructs and the cross-loadings) are consistent with the recommendations of Lacroux (2009); Fornell and Larcker (1981).

Table 6 - Discriminant validity (Fornell and Larcker, 1981).

	Awars	*EP*	*VP*	*LP*	*Det*	*Effi*	*AVE*	*SQRT AVE*
EP	0.608	1	0.597	0.529	0.548	0.578	0.720	0.848
VP	0.500	0.597	1	0.485	0.434	0.474	0.777	0.881
LP	0.556	0.529	0.485	1	0.465	0.488	0.721	0.849
Det	0.763	0.548	0.434	0.465	1	0.794	0.764	0.874
Effi	0.764	0.578	0.474	0.488	0.794	1	0.666	0.816
Awars	1	0.608	0.500	0.556	0.763	0.764	0.606	0.778

Table 7 - Discriminant validity (Cross loading test) (Lacroux, 2009).

	Awars	*Det*	*Eff*	*EP*	*LP*	*VP*	*IU*
Awars1	**0.750**	0.592	0.565	0.481	0.460	0.333	0.130
Awars2	**0.778**	0.501	0.542	0.427	0.439	0.384	0.014
Awars3	**0.804**	0.562	0.612	0.582	0.490	0.451	0.081
Awars4	**0.769**	0.646	0.637	0.438	0.374	0.397	0.035
Awars5	**0.790**	0.676	0.631	0.443	0.415	0.380	0.108
Det1	0.700	**0.891**	0.701	0.498	0.409	0.370	0.012
Det2	0.621	**0.882**	0.659	0.459	0.408	0.392	-0.028
Det3	0.674	**0.849**	0.729	0.481	0.431	0.376	0.087
Effi1	0.649	0.684	**0.800**	0.459	0.351	0.409	0.095
Effi2	0.558	0.576	**0.792**	0.429	0.383	0.371	0.133
Effi3	0.604	0.655	**0.839**	0.449	0.406	0.384	0.070
Effi4	0.683	0.681	**0.831**	0.551	0.463	0.387	0.163
EP1	0.542	0.496	0.532	**0.864**	0.438	0.506	0.184
EP2	0.516	0.416	0.434	**0.855**	0.468	0.542	0.084
EP3	0.507	0.486	0.517	**0.826**	0.450	0.470	0.158
LP1	0.517	0.500	0.463	0.499	**0.877**	0.477	0.063
LP 2	0.435	0.292	0.371	0.400	**0.820**	0.348	0.061
VP1	0.456	0.389	0.441	0.535	0.453	**0.887**	0.115
VP2	0.429	0.376	0.396	0.517	0.412	**0.876**	0.072
IU	0.095	0.027	0.143	0.167	0.073	0.106	**1.000**

Source: data (SMART PLS outputs).

6.2. *The structural model*

Coefficient of determination (R^2)

The R^2 allows an understanding of the contribution of each explanatory variable to the prediction of the dependent variable. Three different thresholds of the multiple R^2 can be considered: if the R^2 value is greater than 0.1, the model is considered significant; if it falls between 0.05 and 0.1, the model is considered marginal; if it is less than 0.05, then the model is considered not significant (Croutsche, 2002).

The results in Table 8 show that all R^2 values for all endogenous latent variables are greater than 0.1, confirming the significance of the model, with the exception of expert power, voice power and legitimate power, which do not have strong explanatory power in the research model.

Stone-Geisser coefficient (Q^2)

The Stone-Geisser Q^2 coefficient is used to evaluate the quality of any structural equation. If the value of Q^2 is positive, the model has good predictive validity, and if the value of Q^2 is negative, the model has poor predictive validity (Tenenhaus *et al.*, 2005).

The results in Table 9 show that all Q^2 values are positive, indicating that the model has good predictive validity.

Table 8 - R-square of the endogenous latent variables.

Constructs	*R^2*	*Result*
Self –Awareness	0.456	Significant
Self-Determination	0.347	Significant
Self-Efficay	0.393	Significant
Empowerment	1	Significant
Expert power	0.025	Not significant
Legitimate power	0.002	Not significant
Voice power	0.008	Not significant

Source: data (Smart PLS outputs).

Effect size f^2

Effect size indicates the relative effect of a given exogenous latent variable on the endogenous latent variable by using the variations in the coefficient of determination (R^2) (Chin, 1998).

The effect size can be expressed with the following formula (Cohen,1988):

$$f^2 = \frac{R^2_{inclue} - R^2_{exclue}}{1 - R^2_{inclue}}$$

The results in Table 10 show that, based on the recommendations of Cohen (1988), the effect size for all relationships between latent variables in the model is characterized by a large effect $f^2 > 0.35$. Generally, the results indicate that the independent variables in the model have a significant

Table 9 - Cross-validation redundancy indices.

Variables	*SSO*	*SSE*	*Q^2 (=1-SSE/SSO)*
Self-Awarness	1500.000	1094.892	0.270
Self-Determination	900.000	663.607	0.263
Self-Efficacy	1200.000	890.078	0.258
Empowerment	2100.000	1022.662	0.513
Expert power	900.000	885.736	0.016
Legitimate power	600.000	598.630	0.002
Voice power	600.000	597.209	0.005
IU	300.000	300.000	

Source: data (SMART PLS outputs).

Table 10 - F-square of the endogenous latent variables.

Constructs	*f^2*	*Result*
Expert power->Empowerment	3779.469	Large
Voice power-> Empowerment	1504.418	Large
Legitimate power->Empowerment	1449.695	Large

Source: data (SMART PLS outputs).

Table 11 - Goodness-of-Fit (GoF).

Constructs	*R²*	*Average of R²*	*AVE*	*Average of AVE*	*GoF Index*
Self-Awarsness	0.456	0,318714	0.60	0,681142	0,465928
Self-Determination	0.347		0.764		
Self-Efficacy	0.393		0.666		
Expert power Voice power	0.025 0.008		0.720 0.777		
Legitmate power	0.002		0.721		
Empowerment	1		0.520		

Source: data (SMART PLS outputs).

Table 12 - Test of research model hypotheses.

Hypotheses	*Relation*	*Original Sample*	*Sample Mean*	*Standard Deviation*	*T Statistics*	*P Values*	*Validity*
H1-a	IU -> EP	0.167	0.164	0.059	2.835	0,005	Accepted
H1-b	IU -> VP	0.106	0.113	0.063	1.678	0,094	Accepted
H1-c	IU -> LP	0.073	0.082	0.063	1.161	0,246	Rejected
H1-d	EP->EMP	0.544	0.544	0.022	25.124	0,000	Accepted
H1-e	VP->EMP	0.333	0.333	0.016	18.941	0,000	Accepted
H1-f	LP->EMP	0.310	0.309	0.017	18.803	0,000	Accepted

Source: data (SMART PLS outputs).

impact on the dependent variables, which is considered particularly important and significant.

Goodness-of-Fit (GoF)

The GoF fit index is a general validation index for the PLS model. GoF values of 0.10, 0.25 and 0.36 were classified as very low, medium and high (Wetzels *et al.*, 2009). The formula for calculating the GoF is as follows:

$$\mathrm{GoF} = \sqrt{\overline{\mathrm{R^2}} * \overline{\mathrm{AVE}}}$$

The results in Table 11 show that the Goodness of Fit (GoF) for this study is 0.465. In agreement with the values reported by Wetzels *et al.* (2009), these results indicate a strong overall quality of the model. This means that the PLS model fits the observed data well and can be used to make accurate predictions.

Hypothesis testing

Table 12 shows the results of the hypothesis test of the research model using the bootstrapping method and selecting 500 replicate samples, as recommended by Chin (1998).

7. Results and discussion

The aim of this study is to provide a theoretical understanding and empirical investigation of the impact of the use of Internet and web technologies on consumers' power over food, and consequently, on their psychological empowerment in food choices. To achieve this goal, power and empowerment theory were used as a theoretical framework to analyze the consumer empowerment phenomenon in food.

The results in Table 12 confirm a positive and significant relationship between the use of Internet and web technologies and consumers' expert power over food (p-value = 0.005). These results are consistent with previous research by Pitt *et al.* (2002), Nam (2019) and Li *et al.* (2022), which improve significantly the understanding of the impact of Internet use on consumers' information power. That is, consumers who use the Internet have increased their expert power (Pitt *et al.*, 2002), especially in the area of food (Nam, 2019). With access to a large amount of information about food, consumers can learn

about the nutritional properties of the foods they consume and understand how these foods affect their health (Li *et al.*, 2022).

The second hypothesis (H1b) was confirmed as there is a significant relationship between Internet use and consumer voice on food issues (p-value = 0.094). These results are consistent with previous research by Labrecque *et al.* (2013); Hennig-Thurau *et al.* (2004); Pruche (2015) and Hirschman (1970), who discuss the importance of the impact of Internet use on consumer voice in the producer-consumer relationship, i.e. consumers can exercise their power of reward and coercion based on the information they find (Labrecque *et al.*, 2013; Pruche, 2015).

Labrecque *et al.* (2013) and Pruche (2015) point out that consumers can exercise their power of reward or coercion depending on the information they find. For example, if a consumer finds harmful ingredients in a product, they may choose not to buy it, while if they find healthy ingredients, they may choose to buy it (Hirschman, 1970). Access to nutrition information on the Internet has empowered the voice of consumers, enabling them to make informed choices about their diet and exercise their power over reward and coercion accordingly (Hennig-Thurau *et al.*, 2004).

The third hypothesis (H1c) was rejected because the relationship between Internet use and legitimate power over food was not significant (p-value = 0.246). These results are contradictory to previous studies that examined the impact of Internet use on consumers' legitimate power over food (Levkoe and Blay-Palmer, 2018; Moati, 2009; Fayn *et al.*, 2019). This contradiction means that consumers do not feel that they are legitimate decision-makers on food issues, which means that they have not yet strengthened their legitimate power in this area. Nutrition experts and food companies are more likely to be seen as legitimate decision-makers on nutrition issues. However, using the Internet to learn about nutrition can be seen as a step towards strengthening their power.

The fourth hypothesis (H1d) was confirmed as the relationship between expert power and consumer psychological empowerment in food was significant (p-value = 0.000). These results are consistent with previous research by Pruche (2015); Wang *et al*. (2020) and Nam (2019), suggesting a positive relationship between consumers' expert power in food and their psychological empowerment. That is, greater access to information enables consumers to acquire expert knowledge about food, which enables them to make more informed and responsible decisions about what they buy and consume (Wang *et al*., 2020). This expert knowledge also gives them a sense of autonomy and control over their food, strengthening their self-determination in food choices and their role in the food market (Nam, 2019).

The fifth hypothesis (H1e) was confirmed as the relationship between voice power and psychological empowerment was significant (p-value = 0.000). These results are consistent with previous research by Pruche (2015), Wang *et al.* (2020) and Nam (2019) suggesting a positive relationship between consumers' voice power in food and their psychological empowerment in food choices. This means that consumers have gained reward and coercive power over food through the Internet. Namely, they can express either their satisfaction, or dissatisfaction regarding food through online comments, social media reviews and blogs. This reward and coercion power strengthens their decision-making power over food; as food companies have an incentive to respond to consumers' demands in order to retain their customer base (Wang *et al.*, 2020). Consumers are thus able to influence companies' food practices by using their power of reward and coercion via the Internet, which strengthens their decision-making power over their food choices (Nam, 2019).

The sixth hypothesis (H1f) was confirmed as the relationship between legitimate power over food and consumers' psychological empowerment in their food choices was significant (p-value = 0.000). These results are consistent with previous research by Pruche (2015), Nam (2019), and Wang *et al.* (2020) suggesting a positive relationship between legitimate power over food and consumers' psychological empowerment in their food choices. That is, consumers' legitimate power over food enhances their agency in making food choices (Wang *et al.*, 2020). Consumers have increasing choices about food and can influence the practices of food companies through

their purchasing power and collective voice. When consumers have the opportunity to influence food industry practices, it can strengthen their sense of power and influence (Nam, 2019).

8. Conclusion

This study shows that the use of the Internet has a significant impact on consumers' power over food, as they have access to a large amount of information about food products. This allows consumers to increase their expert power and make more rational decisions based on their needs and values. They can also exercise their coercive power by boycotting products or companies that do not meet their expectations and their reward power by promoting those that do. Despite these advances, however, consumers still do not have legitimate power over food, and accountability campaigns as the « c'est qui le patron ? » brand, which aims to make them aware of the impact of their choices on the food chain.

To sum up, the information available through the Internet and technology enables consumers to make informed decisions about food, provides them with knowledge and a platform to voice their opinions, and represents a crucial first step towards obtaining genuine control over the food industry. Ultimately, consumer empowerment has a positive impact by prompting the food industry to increase transparency, accountability, and responsiveness to consumer needs and expectations.

Theoretical contributions

Theoretical contribution of this study is focused on empowerment theory to investigate the phenomenon of consumer empowerment in food. The study introduces the vision of (Ben Ayed and El Aoud, 2016) to strengthen the validation of the scale. This scale was identified in the literature review for patients with chronic diseases who are involved in managing their condition with doctors. The study adapts the scale to the context of a consumer who becomes aware of his food choices and seeks to collaborate with brands. This aligns with the research model and is tested to assess its relevance in the Moroccan context.

Economic implication

The findings of this study show that consumer power over food is a growing phenomenon and has significant economic implications. Consumers have increasingly more power when it comes to food. This has led to an increasing demand for organic, local and sustainable food, as well as increased transparency and accountability from food companies. Companies that meet these consumer expectations are seeing increased demand, while those that fail to adapt risk losing market share. To meet this new demand and promote consumer empowerment of their food, food companies can create transparency and improve communication, adapt to new consumer trends, invest in consumer education and encourage consumer participation in product development. Adopting these practices can promote consumers empowerment of their food and lead to better health and greater consumers confidence in the food they buy.

Similarly, the study's findings could have important implications for food companies and policy makers. Companies may need to adapt their marketing strategy to better meet the needs of more informed and demanding consumers. Governments may need to take action to protect consumer rights, for example in food labelling and the regulation of online food advertising. In addition, the findings could encourage innovation in food technology, such as the development of mobile apps that help consumers make informed decisions about their food.

Limits and perspectives research

The random sampling method used in this study may have limitations that undermine its validity and generalisability and lead to biased results. Although the random sampling method may be useful in some studies, it has significant limitations in quantitative studies. Individuals selected solely for convenience may not be truly representative of the population as a whole, as they may have particular characteristics that distinguish them from the rest of the population. The conclusions of a random sample may therefore not be generalisable to the whole population, which reduces the external validity of the results. Therefore, researchers should be aware

of these limitations in future studies and consider some measures to reduce the risk of representativeness: clearly define the target population, use multiple sources to recruit participants (nutrition website, online nutrition discussion forum), collect information on participants' characteristics such as age, gender, education level, socioeconomic status, etc.

This study can also provide other directions for future research in the field of empowerment. The results obtained in this study can be used to explore new research paths on the phenomenon of empowerment using nutritional applications instead of the Internet and web technologies. This could expand the scope of empowerment research and better understand how new technologies can contribute to improving individuals' health and well-being. In summary, it is important to continue exploring new research paths to strengthen individuals' empowerment using new technologies.

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Annexe 1

Questionnaire

This research work aims to assess the impact of Internet and technology usage on consumer power in the field of food, and therefore on their psychological empowerment
Have you used the Internet to search for information before purchasing a food product that you consume?* ☐ Yes ☐ No
Has the Internet and web technologies, helped you to obtain more information to know whether a product is good for your health?
Thanks to the information provided by the Internet and web technologies
I am better positioned to make a good choice among the available food offers* Not at all agreed 1 2 3 4 5 Totally agree
I have all the information I need to make an informed purchase* Not at all agreed 1 2 3 4 5 Totally agree
I feel capable of choosing my consumption* Not at all agreed 1 2 3 4 5 Totally agree
It has become easy for me to share reviews with consumers* Not at all agreed 1 2 3 4 5 Totally agree
I know that I can raise my voice whether I am satisfied with my consumption or not* Not at all agreed 1 2 3 4 5 Totally agree
The opinion of the consumer has become important for the producer* Not at all agreed 1 2 3 4 5 Totally agree
I can influence consumers through the products I consume* Not at all agreed 1 2 3 4 5 Totally agree

I have the ability to adjust the ingredients of the product if the brand allows it*
Not at all agreed 1 2 3 4 5 Totally agree
How do you rate your level of information for choosing a food product with the boom of nutritional information provided by the Internet?
I think I am the person who knows best about his or her health status and needs*
Not at all agreed 1 2 3 4 5 Totally agree
I am aware of situations and experiences that can have a negative influence on my decisions*
Not at all agreed 1 2 3 4 5 Totally agree
I know where to find information to take care of my consumption*
Not at all agreed 1 2 3 4 5 Totally agree
I know how to take care of my health by being mindful of what I consume*
Not at all agreed 1 2 3 4 5 Totally agree
I am very concerned about my health: (choice of food, products, their composition, etc.)*
Not at all agreed 1 2 3 4 5 Totally agree
I have control over myself and know what is good for my health*
Not at all agreed 1 2 3 4 5 Totally agree
I show independence and responsibility for myself*
Not at all agreed 1 2 3 4 5 Totally agree
I can choose healthy eating goals*
Not at all agreed 1 2 3 4 5 Totally agree
I can choose my consumption according to my nutritional goals*
Not at all agreed 1 2 3 4 5 Totally agree
I am able to understand the difficulties that arise in my consumption decisions
Not at all agreed 1 2 3 4 5 Totally agree
I am able to decide which way is the best for me to reach my nutritional goals
Not at all agreed 1 2 3 4 5 Totally agree
I believe that I can sustain a long-term dietary change*
Not at all agreed 1 2 3 4 5 Totally agree

Profile of respondents

Your gender*	**Your age**	**Your level of education***	**Your professional status***	**Your salary**
Male Female	Less than 25 years old 25-35 years old 46 -55 years old 56-65 years old More than 65 years old	Bachelor's degree 2-year university degree 3 or 4-year university degree 5-year university degree 8-year university degree	Student Employee Civil servant Entrepreneur Self-employed Others	No salary Less than 5000DH 5000-10000 DH 10000-20000 DH 20000-30000 DH More than 30,000 DH

Analysing export performance in Spanish agro-food auxiliary companies: The role of eco-innovation

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Abstract

The main objective of this study is to contribute to the existing debate on the link between export activity and eco-innovation at a microeconomic level, using Spanish agro-food auxiliary companies as case study. For that purpose, a cluster analysis has been carried out and two groups of companies have been identified, that is low and high export performance. The languages spoken in the company, export revenues, export experience, international promotion expenses and positioning strategies are the variables that most contribute to distinguishing these groups. The results also show that the age of the management is a key factor in being more export-oriented, as are the control of inputs through information and communication technologies, the implementation of environmental innovations, and partnerships with universities and research centres. The main contributions of this study are: firstly, to broaden the sectoral scope of the research, which was previously focused on the industrial sector; secondly, to analyse the factors that can influence strategic decision-making; finally, the results provide information of interest to companies that wish to increase their eco-innovative processes through export orientation.

Keywords: *Export performance, Environmental innovation, Cluster analysis, Agro-food sector, Auxiliary industry.*

1. Introduction

R&D activities are vital in providing a competitive advantage for any activity and economic sector. In the case of the agro-food sector, several studies have demonstrated the relevance of these activities as one of the main factors for growth and achieving a more solid competitive position in both national and international markets (Capitanio *et al.*, 2009). This point is becoming increasingly decisive in an agro-food context characterised by progressively globalised competition and a higher level of demand (Baamonde, 2009).

Moreover, economic internationalisation has led to an ever-growing loss of local markets, with a resulting increase in transport distances between growers, industry and consumers, with repercussions on social and environmental costs (Notar-

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nicola *et al.*, 2012; Reisch, 2013). In this context, the search for sustainable production and consumption in the agro-food sector has stimulated the creation of many international initiatives and strategies designed to reduce environmental impacts, forcing companies to increase their productivity and export capacity through eco-innovative processes. The relationship between internationalisation and innovation is more widely studied in the literature (e.g. Freixanet, 2014; Shearmur *et al.*, 2015; Bıçakcıoğlu-Peynirci *et al.*, 2020). On the contrary, specific studies on eco-innovation are more limited (de Jesus Pacheco *et al.*, 2017). Numerous authors agree that international trade can have a positive effect on actions aimed at improving environmental performance (Triguero *et al.*, 2017; Galbreath, 2019).

Along these lines, several studies analyze export performance (EX) and eco-innovation (EI) relationship (e.g. Choi and Yi, 2018; Horbach and Jacob, 2018; Muñoz-Pascual *et al.*, 2019), but the conclusions drawn offer a very generalised view. At a microeconomic level, only 25% of theses works examine whether EI helps companies increase EX. Nevertheless, most of them (75%) analyze the influence of EX on EI, confirming mostly a positive effect (Sorroche-del-Rey *et al.*, 2022). Moreover, it can be observed that most of the analyses have focused on the industrial sector, and the evidence in the agro-food sector is very scarce.

In this context, the present study examines this issue in greater depth, taking Spanish agro-food auxiliary companies as a reference. Specifically, we examine the relationship between export performance and organisational and technological eco-innovations, identifying the characteristics, variables and dimensions that contribute towards setting firms apart. In addition, this study also shows how export performance indirectly influences EI through control variables, the main objective being to understand how the export performance affects adoption of sustainable innovation strategies in this sector.

To this end, a cluster analysis of agro-food auxiliary companies is performed. The results highlight the existence of two groups of companies according to their export orientation. The differences between the two groups depend to a large extent on export experience, export revenues, the amount of importance placed on lowering environmental impact, control of inputs through ICT and external collaboration. All of these show that there is a positive dependence relationship between the export performance and the EI variables.

Thus, this paper complements the scarce literature available regarding the interrelationships between these variables on the agro-food sector, making an empirical contribution.

The rest of the paper is structured as follows. Section 2 contains a review of the literature. Section 3 describes the methodology and materials used. Section 4 explains the estimates and results of the descriptive analysis and the cluster analysis. Section 5 deals with the main discussions. Finally, section 6 presents the conclusions drawn from the research.

2. Literature review

Environmental sustainability has become a priority in recent years, not only for polluting countries, but also for those with greater environmental awareness and commitment. This has led researchers to study how innovations carried out at an environmental level affect export activity and internationalisation processes and vice versa (Chiarvesio *et al.*, 2015; Pozzobon Palma *et al.*, 2018; Muñoz-Pascual *et al.*, 2019; Galera-Quiles *et al.*, 2021).

Today, world population growth along with demographic changes, globalization, andchanges in eating habits are putting upward pressure on the demand for food.This has resulted in profound changes in food production and consumption patterns. The main concerns are to provide enough food, in the quantity and quality required to meet the nutritional needs, while conserving natural resources (Alexandratos and Bruinsma, 2012; Valls *et al.*, 2021). As a result, production is becoming increasingly globalised and industrialised, leading to standardisation. Agricultural practices, especially in developed countries, have intensified in order to increase crop yields as much as possible. At the same time, new production practices are being implemented that foster improved levels of food safety, such as

biological control and the implementation of traceability (Barth *et al.*, 2017). In this regard, Galdeano-Gómez *et al.* (2017) show how innovations in biological control minimise the use of fertilisers and plant protection products in order to promote sustainability in Spanish agricultural production.

The agro-food sector totals approximately 1.3 billion tons annually with a cost of more than 1000 billion dollars per year (Esposito *et al.*, 2020). It has been severely affected by problems such as resource scarcity, food loss and waste generation along the world's supply chain. The mismanagement of resources and processes represents one of the causes of such problems. The food industry also has a negative impact on the environment in terms of energy use, CO_2 and hazardous waste, among others, accounting for 64% of European industrial pollution. As a result, there is a need to find out whether measures are being taken by agro-food companies to promote EI and how this affects their competitiveness and profitability (García-Granero *et al.*, 2020).

Furthermore, greener production and processes must go hand in hand with organisational and commercial eco-innovation as a way of mitigating the environmental externalities of agriculture and the subsequent related international food crises, from a multidimensional approach (Galera-Quiles *et al.*, 2021). In line with the above, it requires the implementation of new green practices that favour the improvement of food safety, towards healthier and more natural products (Arfaoui *et al.*, 2022) and sustainability levels throughout the supply chain. Key factors could be the promotion of EI in different areas (products, processes, planning, technology and R&D); the cooperation between researchers and enterprises (Petruzzella *et al.*, 2020), cooperation between stakeholders in the effective implementation of EI (Kulak *et al.*, 2016), environmental attitudes, perceptions and intentions of decision-makers; environmental concern at management and staff level and the implementation of greener organisational business models (Barth *et al.*, 2017; Drejeris and Miceikienė, 2018).

Accordingly, as these are essential goods, studies in this area should be stepped up because of the implications, not only for the environment, but also for society.

Within the observed heterogeneity, most of the EI in the agro-food industry focuses on products or processes such as the following: cleaner technologies, energy efficiency and renewable energy (Sala *et al.*, 2017); better management of material and other resource flows (van Bommel, 2011; Salomone *et al.*, 2016); greener inputs and raw materials (Salomone *et al.*, 2016; Silalertruksa *et al.*, 2017); food waste levels (Sala *et al.*, 2017); and recycling (Salemdeeb *et al.*, 2017). Other types of EI are included in the organisational dimension, such as improved greener networks as well as inter-organisational cooperation and interaction (Kulak *et al.*, 2016), sharing of regulatory and interpretative schemes (Van Bommel, 2011), guidance on environmental management, sustainability-minded staff and the involvement of environmental experts (do Canto *et al.*, 2021). Finally, ecolabels and quality certifications are also prominent (Goossens *et al.*, 2017). When there is an effective channel leader with influence over the other players, eco-innovation can spread from one company to another as a result of increased collaboration (Hall, 2006).

Implementing eco-innovative processes helps companies solve existing externality problems, in doing so, improving their image with national and international customers (Chiarvesio *et al.*, 2015), and allowing them to increase their profitability and be more competitive as part of a global positioning strategy. In addition, leaders within companies influence strategy and culture. They expand and refine product and process development, and also determine levels of strategic action, including those related to EI (Galbreath, 2017).

In the present study, through the empirical analysis conducted, we tried to include as many of the variables mentioned is possible, in order to determine their influence on the EX and EI relationship in the particular case of the agro-food auxiliary companies.

3. Methodology

The design of our methodology has been divided into several parts. Firstly, we identified the variables and indicators most commonly used in studies on this topic. Secondly, a questionnaire was devel-

oped as a tool to collect the necessary data. Thirdly, a statistical analysis of data including a cluster analysis (k-means procedure) and a chi2 analysis (Piedra-Muñoz *et al.*, 2017) was carried out to determine the influence of the different variables on EX and EI activity interrelationship.

3.1. *Definition of the variables*

As part of the analysis of export performance, EX, a series of the most frequent indicators used in this line of study have been considered (see Table 1): income received from exports, international trade missions and fairs, export experience, the budget allocated for foreign promotion and the degree of establishment in the international market (Valdiviezo, 2012; Chiarvesio *et al.*, 2015; Freixanet, 2014).

In terms of EI, most papers analyse variables related to the expenditure made on eco-innovation by the firm (Galbreath, 2017), the importance of EI in organisations (García-Granero *et al.*, 2020), the use of technologies and activities that help reduce environmental damage and input consumption, as well as the use of recycled packaging (Rodríguez and Wiengarten, 2017;

Table 1 - Variables included in the analysis and scale.

Name of variable	*Description*	*Measurement scale*	*References*
Characteristics of the managing director			
Age	Age of the managing director	Natural number	Sousa *et al.*, 2008
Education	Managing director's level of education (1=no education, 2=primary, 3=secondary, 4=higher education, 5=university)	Liker scale (1-5)	Contractor *et al.*, 2005
Managing director's Gender	Gender of the managing director (=0 male; =1 female)	Dichotomy	Galbreath, 2017
Characteristics of the firm			
Employment	Number of employees	Natural number	Sousa *et al.*, 2008; Chiarvesio *et al.*, 2015
Total income	Total annual income	Thousands of €	Chiarvesio *et al.*, 2015
Education level of employee	Average educational level of company staff (1=no education, 2=primary, 3=secondary, 4=higher education, 5=university)	Liker scale (1-5)	Sousa *et al.*, 2008
Export performance variables			
Languages	Number of languages spoken in the company	Natural number	Sousa *et al.*, 2008; Bianchi *et al.*, 2018
Export Income	Export revenues received as a percentage of total revenues	Percentage	Salomon & Shaver, 2005; Chiarvesio *et al.*, 2015; Freixanet, 2014
Trade Misions	Number of international trade missions carried out in 2019	Natural number	Freixanet, 2014
International Fairs	Number of international trade fairs attended in 2019	Natural number	Freixanet, 2014
Export years	Number of years the company has been exporting	Natural number	Salomon & Shaver, 2005
International promotion	Expenditure on international promotion campaigns (1=€0-15.000; 2=€15.000-30.000; 3=€30.000-45.000; 4=€45.000-60.000, 5= +€60.000)	Liker scale (1-5)	Valdiviezo, 2012
International establishment	Method of establishment abroad (1=does not export, 2=online channel, 3=directly, 4=local sales office, 5=subsidiary)	Liker scale (1-5)	Chiarvesio *et al.*, 2015; Freixanet, 2014

García-Granero *et al.*, 2020); the introduction of external environmental audits (Zailani *et al.*, 2012; Chiarvesio *et al.*, 2015; García-Granero *et al.*, 2020) and collaboration with EI research centres (Chiarvesio *et al.*, 2015; Doloreux and Kraft, 2019).

With respect to the control variables regarding company characteristics, several factors have been taken into account, namely: the number of employees, frequently used as a measure of firm size (Sousa *et al.*, 2008; Chiarvesio *et al.*, 2015), total annual revenue (Chiarvesio *et al.*, 2015) and employees' level of education (Sousa *et al.*, 2008). Also, the main characteristics of managing directors have been considered, such as age (Sousa *et al.*, 2008) and educational level (Contractor *et al.*, 2005).

3.2. *Data collection and sampling*

The southeast of Spain has become the principal horticultural supplier in Spain and Europe. This area includes the world's largest concentration of greenhouses (35,000 ha) to produce fruit and vegetables. The success of this model is not only due to the agriculture

Name of variable	*Description*	*Measurement scale*	*References*
Eco-innovation variables			
EI implementation	If the company has carried out EI (0 =no; 1 = yes)	Dichotomy	Galbreath, 2017
EI expenditure	Percentage of total expenditure spent on EI measures (1: <2.5%, 2: >2.5% <5%; 3: <5% <10%; 4: >10% <15%; 5: >15%)	Liker scale (1-5)	Galbreath, 2017; García-Granero *et al.*, 2020
EI areas	Areas in which EI has been carried out (1=product, 2=process, 3=management, 4=marketing, 5=not done)	Liker scale (1-5)	Doran & Ryan, 2016; García-Granero *et al.*, 2020
Input control	Extent to which input control is carried out using ICT tools.	Liker scale (1-5)	Kante *et al.*, 2016 Rodríguez & Wiengarten, 2017
Initiatives to reduce environmental damage	Extent to which action is taken to reduce environmental damage	Liker scale (1-5)	Rodríguez & Wiengarten, 2017; García-Granero *et al.*, 2020
Clean technologies	Extent to which clean or zero residue technologies are used	Liker scale (1-5)	Rodríguez & Wiengarten, 2017; García-Granero *et al.*, 2020
Suppliers with EI culture	Extent to which suppliers with an eco-friendly culture are selected	Liker scale (1-5)	Lawson *et al.*, 2015; Kulak *et al.*, 2016
Solutions to reduce water, energy, plant protection or fertiliser consumption	Extent to which solutions to reduce the consumption of water, pesticides, energy and/or fertilisers are developed.	Liker scale (1-5)	Rodríguez & Wiengarten, 2017; García-Granero e*t al.*, 2020
Use of recycled packaging and materials	Extent to which recycled packaging is used	Liker scale (1-5)	Rodríguez & Wiengarten, 2017; García-Granero *et al.*, 2020
Research centres	Extent of collaboration with universities or research centres	Liker scale (1-5)	Chiarvesio *et al.*, 2015; Doloreux & Kraft, 2019
ISO 14001 Certification	If 14001 certified (0=no; 1=yes)	Dichotomy	Chiarvesio *et al.*, 2015
Environmental auditing	If environmental auditing is carried out (0=no; 1=yes)	Dichotomy	Chiarvesio *et al.*, 2015; García-Granero *et al.*, 2020

Source: Compiled by the authors.

but also to all the synergies that it has originated in auxiliary companies.

For this reason, this study focuses on the Spanish southeast agrifood auxiliary companies, which provide the necessary technologies and services within the value chain to produce fruit and vegetables, such as manufacturers of greenhouses, plastics, containers and packaging, fertirrigation systems, agricultural machinery, climate control, seeds, nurseries, substrates, plant nutrition or integrated pest control. The major destinations are Spain, European Union and developing countries, located mainly in North Africa, Latin America or Asia. In this region, agricultural activity has a major impact on the environment, as it involves an intensification in the use of natural resources (mainly land and water), together with the generation of large amounts of waste (Tolón-Becerra *et al.*, 2013). These negative factors have led to the development of eco-innovative actions (García-Granero *et al.*, 2020).

Data for this study was collected by means of a survey designed specifically for this purpose. The questionnaire was devised taking into account the measures and indicators shown in Table 1 (Evans *et al.*, 2008) and was geared towards the management and technical staff of the companies, as key informants in having an overview of what is really happening in their organisations (Glick *et al.*, 1990). The questionnaires were sent by email and respondents were subsequently contacted by telephone to verify the responses received.

The questionnaire was sent out from August to November 2020 to the 144 agrifood auxiliary companies located in the southeast of Spain. The percentage of responses was quite high. Seventy-one surveys were received, although some were discarded due to incompleteness. Thus, the final sample consisted of 63 surveys which were considered valid for the analysis. This represents a response rate of 43.7%, which is highly satisfactory. According to Menon *et al.* (1996), the average top management survey response rate is in the range of 15-20 percent. In addition, there was a response from all the subsectors. Thus, we consider that the sample is adequate in terms of size and representativeness.

3.3. *Methods*

The cluster methodology was used to identify the number of groups, maximising the heterogeneity between them (Kobrich *et al.*, 2003). We firstly tested the influence of EI on EX and clusterized based on EI, but the results were not satisfactory, in line with those obtained by Mao (2022), for example. As most of the studies found in the literature on this topic (Sorroche-del-Rey *et al.*, 2022), we then studied the influence that export performance could have on the eco-innovative behavior and this analysis showed a positive relationship, expanding the evidences in the less-analyzed agri-food field.

The hierarchical method (Ward's method) was applied to separate the sample into two homogeneous groups: Group 1 (non or low export-oriented companies) and Group 2 (high export-oriented companies), according to the data shown in the dendogram. Subsequently, k-means clustering (Setyaningsih, 2012) was applied, choosing Euclidean distance as the distance measure (Hair *et al.*, 2006). The data was divided into k clusters at random to calculats the centroid of each cluster, assigning each case to the closest cluster. The new centroids were then calculated and firms reassigned to the one closest to the new cluster. This process was repeated until no more reassignments could be made (Piedra-Muñoz *et al.*, 2017). In addition, an analysis of variance (one-way ANOVA) was carried out to identify statistical differences between the groups (Kuswardhani *et al.*, 2014).

Finally, Chi2 tests were carried out to verify the relationship between the two groups together with the following variables from the socio-economic profile: age, educational level and gender of the managing director, number of employees, qualifications and total income.

4. Results

The main results obtained by applying descriptive statistics, cluster analysis and the Chi2 test are presented below.

4.1. *Descriptive statistics*

Table 2 shows a brief description of the main variables that we have considered in the study, in order to provide a profile of the companies.

Table 2 - Summary of statistics for the main variables of the study.

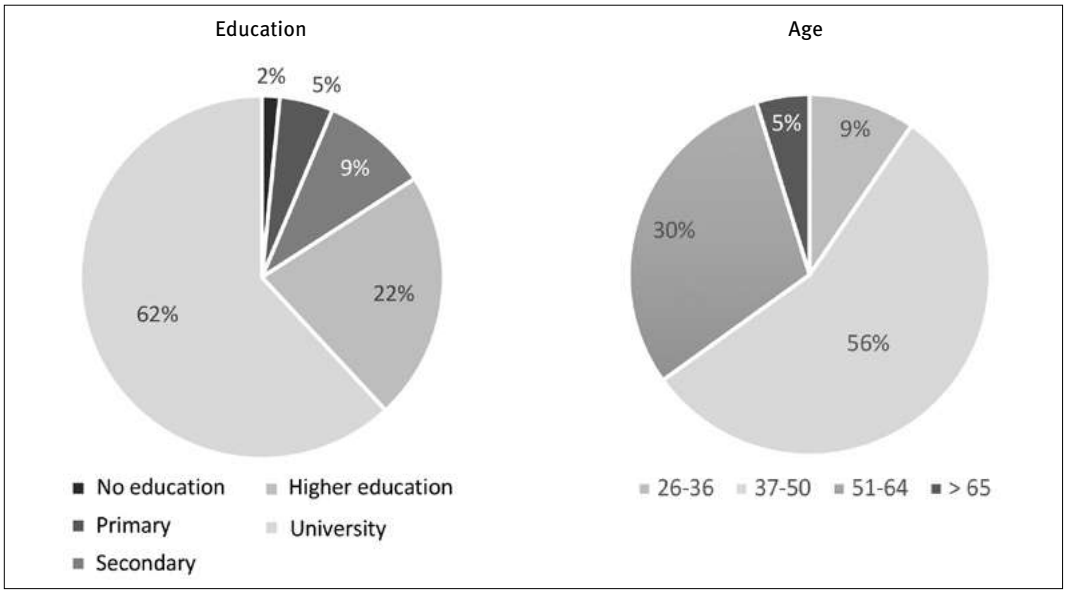
Variable	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*
Personal Attributes of the managing director				
Age	48.29	9.4	26	73
Education	4.38	0.96	1	5
Managing director´s Gender	0.14	0.35	0	1.00
Characteristics of the firm				
Employment	51.63	56.91	4	261
Total Income	10,574.88	19,447.57	268.77	120,000.00
Education of employees	25.19	40.98	1.00	261.00
Export performance variables				
Languages	3.21	1.94	1.00	10.00
Export Income	15.73	21.49	0	77.00
Trade misions	3.30	1.36	1.00	5.00
International Fairs	3.44	1.42	1.00	5.00
Export years	8.06	8.55	0	30.00
International promotion	0.95	1.40	0	4.00
International establishment	1.67	1.50	0	4.00
Eco-innovation variables				
EI Implementation	0.67	0.48	0	1.00*
EI expenditure	1.87	1.90	1	5.00
EI areas	1.08	0.79	1	5.00
Input control	2.41	1.34	1.00	5.00
Initiatives to reduce environmental damage	3.03	1.29	1.00	5.00
Clean technologies	3.02	1.31	1.00	5.00
Suppliers with EI culture	2.83	1.28	1.00	5.00
Solutions to reduce water, energy, plant protection or fertiliser consumption	3.30	1.60	1.00	5.00
Use of recycled packaging and materials	2.89	1.35	1.00	5.00
Research centres	2.94	1.58	1.00	5.00
ISO 14001 Certification	0.27	0.45	0	1.00*
Environmental auditing	0.35	0.48	0	1.00*

(*) Dichotomous variables, 0 or 1. Source: Compiled by the authors.

The results show that the managing directors of the companies surveyed are relatively young, with an average age of 48 years. With regard to their level of education, we found that the vast majority of them have a university education (84%) (Figure 1). Only 14.2% are women, which may be due to the fact that these are agro-food auxiliary activities where women have been under-represented for many years and this has only started changing over the last decade. The average number of employees per company is 51.6, with the level of university studies of the workers being 50.8%, while the average income of the firms is € 10.5 million, so they are mainly small and medium-sized companies.

This is an internationally recognised activity in those countries that are developing or want to develop their agriculture through the implementation

Figure 1 - Personal attributes of the managing directors.



of high-yield greenhouse technology. This must be the reason why 66% of the companies participate in international trade fairs and trade missions, even though they only speak 3.2 languages on average (the maximum being 10), which tells us that they are open to the rest of the world, where language has not been a barrier to breaking into foreign markets where they can sell their technology.

Export revenues as a percentage of the total, amount to an average of 15.7%, the highest figure being 77%. As a result, the companies are highly skewed in terms of its level of exports, with 70% invoicing less than 15% internationally and only 11% invoicing more than 50% abroad.

The average expenditure on promotion abroad is less than € 45,000 in more than 83% of the cases (Figure 2), which makes it difficult for companies to establish themselves internationally.

Figure 2 - Foreign promotion budget and % exports.

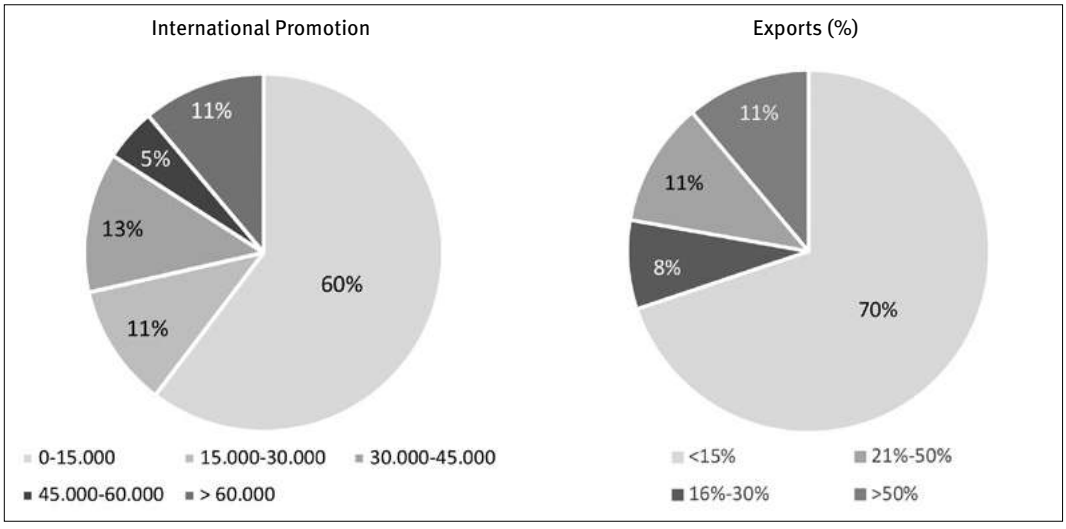
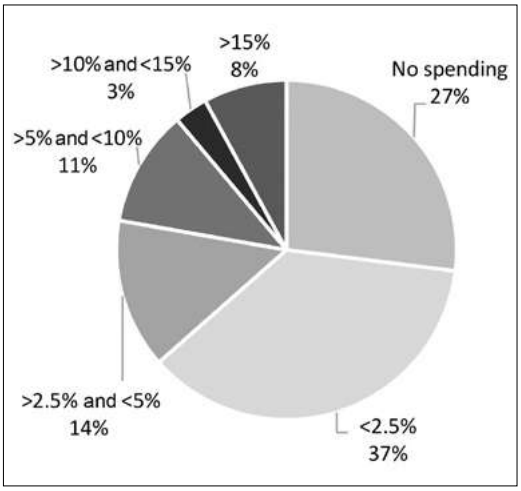


Figure 3 - Percentage of expenditure on EI.



The level of importance given to EI both at company level (4.1) and by managing director is quite high: 4.05 out of 5. More than half (67%) report having undertaken EI actions in their company, although the percentage of expenditure on EI is still too low, with 71% spending less than €30,000 per year (Figure 3). The extent of implementating environmental management systems is 27% in terms of certifications and 35% in terms of audits, despite the fact that they should optimise the use of fertilisers, water and energy consumption, recycling and waste management, both in terms of environmental impact and the costs involved.

Cluster analysis. Types of companies with respect to export performance

The results obtained in the dendogram (Appendix B) determined two groups to be the best solution, as they showed the lowest p-values for a one-way analysis and represented the most significant difference of each variable between the groups. Finally, two homogeneous groups were identified by applying cluster analysis: Group 1 (non or low export-oriented companies) and Group 2 (high export-oriented companies). Subsequently, an analysis of variance (one-way ANOVA) was performed to find statistically significant differences in the means of the variables that comprise each group (Piedra-Muñoz *et al.*, 2017).

The results are shown in Table 3 where the values of the main variables can be observed. The variables that differ significantly between groups with a probability level of 5% (p-value<0.05) and also contribute most to the differentiation between groups, are "Languages", "Export Income", "Export years", "International Promotion" and "International Establishment". These are followed to a lesser extent by "Control of inputs using ICT tools", "Number of collaborations with universities and research centres", "Initiatives to reduce environmental damage", "Eco-innovation has been carried out" and "Age of managing director".

Each of the groups analysed has a set of variables that allow us to characterise each group:

- Group 1. This group corresponds to the companies with lowest export orientation and accounts for 69.8% (44 observations) of the total analysed. The average age of the manager is 46 years (13.2% lower than the age of the other group). The companies in this group have an income level of almost € 8m (€ 7.6m), have been exporting for less than 5 years (4.3), with 5.7% of revenue coming from exports, and speak less than three languages. They have a very low budget for promotional activities (0.4 out of 5), and are 3 times less established abroad than Group 2. With regard to the indicators for EI, we found that only half of the companies in this group carry out activities of this type of innovation, are concerned with carrying out meaures to reduce environmental damage or collaborate with universities and research centres; and less than half undertake input control using ICT.
- Group 2. Corresponds to the companies with highest export orientation and represents 28.6% (18 observations) of the companies analysed. The average age of the manager is over 53 years old. The companies in this group have an average income of almost €18m (17.9m), of which more than 40% (40.6%) corresponds to sales abroad, have extensive export experience of more than 17 years (17.3) and speak more than 5 languages. They have a promotional budget almost 6 times higher than that of the companies that export the least (5.8), and are 3 times more established abroad than companies in Group 2. An analysis of the indicators for EI

Table 3 - Characteristics of identified clusters and test statistics of one-way ANOVA.

	Group 1 N= 45		*Group 2 N=18*			
	Low export performance		*High export performance*			
Variable	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*	*F*	*p-Value*
Personal Attributes of the manager						
Age	46.20	9.260	53.50	7.748	8.719	*0.004*
Education	4.356	1.004	4.444	0.856	0.109	*0.742**
Managing director's Gender	0.156	0.367	0.11	0.323	0.201	*0.655**
Characteristics of the firm						
Employment	43.492	50.782	72.000	67.242	3.349	*0.072**
Total Income	7,618.81	14,323.91	17,965.08	27,701.08	3.804	*0.056*
Education employee	53.79	31.38	43.75	24.818	1.463	*0.231**
Export performance Variables						
Languages	2.360	1.111	5.330	1.970	57.803	*0.000*
Export Income	5.750	9.339	40.690	23.135	74.033	*0.000*
Trade Misions	3.311	1.474	3.278	1.074	0.008	*0.931**
International Fairs	3.220	1.444	4.000	1.237	4.028	*0.049*
Export years	4.360	5.661	17.330	7.515	55.728	*0.000*
International Promotion	0.400	0.889	2.333	1.495	40.268	*0.000*
International Establishment	1.111	1.318	3.056	0.938	32.447	*0.000*
Eco-innovation Variables						
EI Implementation	0.578	0.499	0.889	0.323	5.951	*0.018*
EI expenditure	1.756	2.047	2.167	1.505	0.595	*0.444**
EI areas	0.978	0.866	1.333	0.485	2.681	*0.107**
Input control	2.067	1.232	3.278	1.227	12.449	*0.001*
Initiatives to reduce environmental damage	2.733	1.286	3.778	1.003	9.516	*0.003*
Clean technologies	2.933	1.355	3.222	1.215	0.618	*0.435**
Suppliers with EI culture	2.733	1.372	3.056	0.998	0.816	*0.370**
Solutions to reduce water, energy, plant protection or fertiliser consumption	3.067	1.629	3.889	1.410	3.521	*0.065**
Use of recycled packaging and materials	2.711	1.456	3.333	0.907	2.831	*0.098**
Research centres	2.556	1.470	3.889	1.491	10.492	*0.002*
ISO 14001 Certification	0.222	0.420	0.389	0.502	1.807	*0.184**
Environmental auditing	0.289	0.458	0.500	0.514	2.543	*0.116**

Source: Prepared by the authors.

shows that 88.9% of the companies carry out activities related to this type of innovation and more than 75% are concerned with carrying out measures to reduce environmental damage or collaborate with universities and research centres, as well as undertaking input control using ICT.

Chi-squared tests

To understand the differences between the two groups analysed and the characteristics that determine each of them, a chi-squared analysis was performed. With an error of less than 5%, the analysis shows in the pertinent sections, the areas in which EI has been carried out (Table

Table 4 - Observed and expected frequencies for EI Areas in Groups 1 and 2.

Areas in which EI has been carried out			*1*	*2*	*3*	*4*	*5*	*Total*
Group	*1*	*Observed*	14.0	20.0	10.0	0.0	1.0	45.00
		Expected	10.0	22.9	11.4	0.0	0.7	45.00
	2	*Observed*	0.0	12.0	6.0	0.0	0.0	18.00
		Expected	4.0	9.1	4.6	0.0	0.3	18.00

Pearson's chi-squared test: 7.875; df = 3; p = 0.049.

4), as well as the observed and expected frequencies in groups 1 (Low export performance) and 2 (High export performance). The number of companies determined in Group 2 is higher than expected for the areas in which they have performed EI for values 2 and 3 (they perform some EI for processes and management), meaning they are influenced by factors that drive them to export more.

Tables 5 and 6 show the observed and expected frequencies for firms engaging in EI or not and the % of expenditure spent on EI in both groups. The observed number of firms in Group 2 that implement EI and the observed number in group 1 that spend more than 5% on EI is higher than the expected number, indicating that these firms are influenced by factors that push them to export more in the first case and less in the second, i.e. the higher the EI spending, the less influence there is on their export capacity.

Tables 7 and 8 illustrate the observed and expected frequencies for the degree of importance of both controlling inputs using ICT tools as well as taking action that reduces environmental damage. The observed number of companies in Group 2 is higher than the expected number, for values 4 and 5 in both cases, which indicates that the companies placing great importance on these two eco-innovative actions, are influenced by those factors that drive them to be more export-oriented.

Tables 9 and 10 report the observed and expected frequencies for the use of packaging and recycled material, as well as for collaboration with universities and research centres. The observed number of companies in Group 2 is high-

Table 5 - Observed and expected frequencies for *Engaging in eco-innovation* in Groups 1 and 2.

Engage in eco-innovation			*Do not engage in eco-innovation*	*Engage in eco-innovation*	*Total*
Group	*1*	*Observed*	19.0	26.0	45.0
		Expected	15.0	30.0	45.0
	2	*Observed*	2.0	16.0	18.0
		Expected	6.0	12.0	18.0

Pearson's chi-squared test: 5.600; df = 1; p = 0.018.

Table 6 - Observed and expected frequencies for *% Cost eco-innovation* in Groups 1 and 2.

% cost eco-innovación			*0%*	*1%*	*3%*	*4%*	*5%*	*6%*	*Total*
Group	*1*	*Observed*	16.0	14.0	7.0	1.0	2.0	5.0	45.0
		Expected	12.1	16.4	6.4	5.0	1.4	3.7	45.0
	2	*Observed*	1.0	9.0	2.0	6.0	0.0	0.0	18.0
		Expected	4.9	6.6	2.6	2.0	0.6	1.3	18.0

Pearson's chi-squared: 19.723; df = 5; p = 0.001.

Table 7 - Observed and expected frequencies for *Degree of importance* in Groups 1 and 2.

Degree of importance of controlling inputs with ICT			*1*	*2*	*3*	*4*	*5*	*Total*
Group	*1*	*Observed*	21.0	9.0	8.0	5.0	2.0	45.0
		Expected	16.4	8.6	7.9	9.2	2.9	45.0
	2	*Observed*	2.0	3.0	3.0	8.0	2.0	18.0
		Expected	6.6	3.4	3.1	3.8	1.1	18.0

Pearson's chi-squared test: 12.359; df = 4; p = 0.015.

Table 8 - Observed and expected frequencies for *Extent of taking action to reduce environmental damage* in Groups 1 and 2.

Extent of taking action to reduce environmental damage			*1*	*2*	*3*	*4*	*5*	*Total*
Group	*1*	*Observed*	11.0	7.0	14.0	9.0	4.0	45.0
		Expected	7.9	7.1	11.4	12.9	5.7	45.0
	2	*Observed*	0.0	3.0	2.0	9.0	4.0	18.0
		Expected	3.1	2.9	4.6	5.1	2.3	18.0

Pearson's chi-squared test: 12.285; df = 4; p = 0.015.

er than expected for the use of packaging in levels 3 and 4, which indicates that only the use of certain recycled packaging is influenced by the factors that drive them to be more export-oriented. Regarding collaboration with universities/research centres, the observed number of initiatives is higher in Group 2 and level 5, which indicates that the most export-oriented companies are influenced by the various initiatives they carry out with research centres.

Table 9 - Observed and expected frequencies for *Use of recycled packaging and materials* in Groups 1 and 2.

Use of recycled packaging and materials			*1*	*2*	*3*	*4*	*5*	*Total*
Group	*1*	*Observed*	14.0	6.0	11.0	7.0	7.0	45.0
		Expected	10.7	5.0	13.6	10.0	5.7	45.0
	2	*Observed*	1.0	1.0	8.0	7.0	1.0	18.0
		Expected	4.3	2.0	5.4	4.0	2.3	18.0

Pearson's chi-squared test: 10.094; df = 4; p = 0.039.

Table 10 - Observed and expected frequencies for *Collaboration with universities and research centres* in Groups 1 and 2.

Collaboration with universities and research centres			*1*	*2*	*3*	*4*	*5*	*Total*
Group	*1*	*Observed*	17.0	5.0	10.0	7.0	6.0	45.0
		Expected	13.6	5.0	8.6	6.4	11.4	45.0
	2	*Observed*	2.0	2.0	2.0	2.0	10.0	18.0
		Expected	5.4	2.0	3.4	2.6	4.6	18.0

Pearson's chi-squared test: 13.068; df = 4; p = 0.011.

5. Discussion

Most works that analyze the influence of export activity or internationalization on environmental performance confirm a positive effect (Sorroche-del-Rey *et al.*, 2022). Nevertheless, it should be highlighted that a few of these studies show inconclusive results. For example, Gómez-Bolaños *et al.* (2020) found that firms' level of internationalization had a positive effect on their environmental management, whereas its effect on environmental performance was not found to be significant. In our case study the results showthat there is a positive relationship between EX and EI variables. As such, it can be deduced that export activity contributes towards increasing EI, these results being in line with other studies (Galbreath, 2019; Triguero *et al.*, 2017; Choi and Yi, 2018; Horbach and Jacob, 2018; Muñoz-Pascual *et al.*, 2019).

The results reveal that more than half of the companies (67%) report having undertaken EI actions, although this expenditure is relatively low in 71% of the companies. This may be because there is not yet enough pressure at market or regulatory level to force companies to invest more in taking action that contributes to reducing environmental damage (Keshminder and Chandran, 2017). In our analysis, the most export-oriented firms have a high eco-innovative awareness (Muñoz-Pascual *et al.*, 2019) but there is an inverse relationship when EI spending increases, in contrast to the results of Fonfría (1997), which show how spending on innovative activities raises the possibility of targeting foreign markets. This trend will have to change, as there is growing international environmental concern about pollution levels and input savings (Máté-Balogh and Jámbor, 2020), as well as increased consumer awareness in EU countries (Chiarvesio *et al.*, 2015). Thus, if companies want to be competitive, they will have to adapt to market changes and devote economic resources to developing more sustainable technology (Brunel, 2019), possibly supported by public funding to promote and finance part of these processes, especially in SMEs (Sung *et al.*, 2017), as they have fewer resources to do so.

Regarding the implementation of measures to reduce environmental damage, these are considered of great importance for more than 75% of the most export-oriented companies, which is in line with other works by Pozzobon Palma *et al.* (2018), which point out that the existence of raised social and environmental awareness helps EI to promote EX. Through sustainable product innovation and greener processes, firms' export performance levels increase (Jin and Scheepens, 2016; Carrillo-Labella *et al.*, 2017); along with the use of cleaner technologies, energy efficiency and renewable energy (Sala *et al.*, 2017), as well as better resource management, material flows (Salomone *et al.*, 2016) and recycling (Salemdeeb *et al.*, 2017).

The use of recycled packaging and materials has increased in recent years although its implementation is still very low (Ivanković *et al.*, 2017), despite a concerted awareness campaign to help its adoption (Verghese and Lewis, 2007). Our results show that it is carried out by 66% of Group 2 companies and 54.2% of Group 1 companies, in line with García-Granero *et al.* (2020) where most of the companies are SMEs, which show less propensity for EI, especially in the use of recyclable packaging.

With respect to the companies that carry out EI initiatives, the high percentage of companies in Group 2 (89%) that say they do so stands out, exhibiting a close direct relationship between the two variables, this figure being considerably lower in the companies that export less (58%). The results presented by Carrillo-Labella *et al.* (2017) disagree with ours, as they show that companies belonging to the Spanish olive sector show little voluntary environmental commitment, despite the requirements set out by foreign markets.

The results also reveal that more than 65% of the companies in Group 2 express a great interest in controlling inputs using ICT technologies, with lower figures for companies that export less. The use of ICTs acts as a tool highly valued by companies, as it can help them along the EI journey by providing a user-friendly system (Buttol *et al.*, 2012), playing a key role in providing growers with input information (Kante *et al.*, 2016).

Regarding collaboration with universities and research centres, we find that 77.7% of the most export-oriented companies (Group 2), state that

they do this when undertaking innovation actions. These results are in line with other studies that consider EI as a source of opportunities for exports through cooperation (Constantini *et al.*, 2018). Also Chiarvesio *et al.* (2015) and Doloreux and Kraft (2019) found that collaboration with research centers and universities is a variable used to measure EI since it allows smaller companies to access the necessary resources and increases the environmental knowledge to promote eco-innovations. In this line, Triguero *et al.* (2013) have found that universities and public research institutions are the main contributors to improving firms' EI performance. In this sense, EI requires more external sources of knowledge and information from universities than conventional innovation because the knowledge used in eco-innovation is more multidisciplinary than the knowledge needed in other innovations (Rennings and Rammer, 2011).

In terms of the control variables, age and educational level of the managing director, we find that age is a decisive factor, with the average age of the manager being above 53 years in the most export-oriented companies. It can therefore be deduced that experience influences the decision to export, unlike other studies such as Manolova *et al.* (2002), which concluded that there was no relationship with age. Although they do agree with these studies when it comes to the level of education, it is surprising that the size of the company (workforce and income) does not affect the relationship between EX and EI, unlike Triguero *et al.* (2017) where size plays a key role. In our case, this may be due to the fact that in the agro-food auxiliary companies, rather than depending on size (Chiarvesio *et al.*, 2015), the type of activity the company engages in will have an influence, since we find companies at different technological levels.

Our results also show that the gender of the managing director is not a limiting factor in the relationship between EX and EI, contrary to Galbreath (2019), Horbach and Jacob (2018), who identified a positive correlation between these variables, especially when managing directors are women. This may be because they demonstrate greater sensitivity to the natural environment, having higher moral and ethical standards than men (Galbreath, 2019) in innovative decision-making (Kassinis *et al.*, 2016).

6. Conclusions

The main objective of the study is to illustrate the factors that relate export performance to eco-innovation in the agro-food auxiliary companies. To this end, an empirical study has been carried out, taking Southeastern Spain as a reference, by means of a multivariate analysis using cluster methodology.

The results obtained show that export performance is one of the driving factors behind the increase in eco-innovative activity. This is evident in the degree of importance given to the control of inputs through ICT, when collaborating with universities and research centres and regarding the importance given to action taken that reduces environmental damage. However, it can also be seen that when companies spend more on EI, the impact of exports decreases considerably. This is similar for the use of recycled packaging, since companies report that it tends to be of interest as an innovation which improves environmental performance, but is not yet seen as a key export driver.

On the other hand, the group of less export-oriented companies is smaller in terms of both turnover and number of employees, as well as having less export experience. They show a lack environmental awareness, little commitment to reducing environmental damage and no control of inputs through ICT.

The analysis on the EX-EI relationship helps to guide companies around the factors that can help their international development strategy and the implementation of certain eco-innovative actions that improve environmental practices. The results also have certain repercussions and implications for policy makers, as they can help them to define environmental policies that promote greater sustainability in the agro-food activity.

Nevertheless, this study is not without its limitations, in particular, as it only examines agro-food auxiliary companies in Southeastern Spain, and it would be advisable to extend it to other regions or areas specialising in this activity. Futhermore, possible changes in incomes and exports before and after the introduction of eco-efficient

methods could be also an interesting future line of research. The results show the need for further research that includes other quantitative variables to measure the EX-EI interrelationship in the agro-food sector, allowing the generalisation of the results and assisting in the strategy and decision-making of company managing directors.

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Assessing the sustainability of beekeeping farms in Turkey: Case of the Aegean region

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Abstract

The aim of this study is to determine the sustainability level of beekeeping farms in the provinces of Aydın, İzmir, and Muğla in the Aegean region of Turkey. The data were collected through a questionnaire from 149 selected beekeeping farms during 2018-2019. The study utilized Principal Components Analysis (PCA) to identify 19 basic sustainability indicators for beekeeping farms, which were categorized into economic, social, environmental and general sustainability indicators. Subsequently, the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) was employed to determine the weight of each indicator, considering expert opinions. The results showed that the economic sustainability index of beekeeping farms was 0.45, social sustainability was 0.36, environmental sustainability was 0.92, and the overall sustainability was 0.58. The study determined that 14.77% of apiaries in the selected farms were unsustainable, while the sustainability of 38.93% was at risk. The results also showed that trans-regional migratory beekeeping harmed sustainable beekeeping due to its negative effect on both bee welfare and cost increase.

Keywords*: Beekeeping Farms, Sustainability, Composite Sustainability Index, Principal Components Analysis, Fuzzy Analytical Hierarchy Process.*

1 Introduction

Beekeeping is an agricultural activity that can be pursued independently of soil conditions and is directly linked to climate, plant diversity, and care. In addition to honey, valuable beekeeping products include beeswax, pollen, propolis, royal jelly, bee bread (perga), and bee venom, which are widely used in traditional and modern medicine (Akçiçek and Yücel, 2015). Furthermore, beekeeping provides living materials such as queen bees, package bees, and artificial swarms to the beekeeping industry (Kouchner *et al.*, 2019). Pollination by bees is also essential for seed and food production. Bee pollination enhances the yield, nutritional value, and quality of many fruits and vegetables, extends their shelf life, and supports reforestation. The production of oilseeds used for biofuels, such as sunflower, rapeseed, and canola, is also improved by bee pollination. The resulting increase in agricultural productivity contributes to the gross domestic product (GDP) of countries. Given the role of beekeeping in pollination, ensuring its economic sustainability is also crucial for food safety (Patel *et al.*, 2021; Apimondia, 2022). In addition to the pollination services provided by honeybees, which have environmental benefits, beehives are considered one of the most reliable

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Table 1 - Impact of beekeeping on SDGs.

No	*Sustainable Development Goals (SDGs)*	*Impact of beekeeping on SDGs*
1	No Poverty	Beekeeping can provide a source of income for people in impoverished areas, as honey and other value-added bee product can be sold for profit.
2	Zero Hunger	Beekeeping can increase food production by improving crop yields through pollination, as well as providing a source of honey and other bee product as nutritious food.
3	Good Health and Well-being	Beekeeping is a therapeutic activity in itself and can provide a source of natural medicine.
4	Quality Education	Beekeeping can be used as an educational tool to teach people about the importance of pollinators, biodiversity, and environmental stewardship.
5	Gender Equality	Beekeeping can provide opportunities for women to participate in economic activities and improve their socio-economic status.
6	Clean Water and Sanitation	Bees play an important role in pollinating plants that help purify water sources.
7	Affordable and Clean Energy	Beeswax can be used as a sustainable and renewable energy source in the production of candles and other products.
8	Decent Work and Economic Growth	Beekeeping can provide opportunities for employment and economic growth in rural areas.
9	Industry, Innovation and Infrastructure	Beekeeping can promote innovation and sustainable practices in agriculture and food production. For example A major trend in beekeeping is the use of electronic information tools for monitoring and teaching.
10	Reduced Inequalities	Beekeeping can provide economic opportunities to marginalized communities, helping to reduce inequality.
11	Sustainable Cities and Communities	Bees can play a vital role in urban agriculture and promoting biodiversity in cities.
12	Responsible Consumption and Production	Beekeeping promotes sustainable agriculture practices and the production of natural, organic products.
13	Climate Action	Bees and other pollinators are essential to maintaining healthy ecosystems and mitigating climate change.
14	Life Below Water	Bees and other pollinators can help maintain the health of aquatic ecosystems by pollinating water-dependent plants.
15	Life on Land	Bees and other pollinators play a critical role in maintaining terrestrial ecosystems and biodiversity.
16	Peace, Justice and Strong Institutions	Beekeeping can promote sustainable agriculture and economic development, contributing to peaceful and just societies.
17	Partnerships for the Goals	Beekeeping requires collaboration and partnerships between various stakeholders, including beekeepers, farmers, and policymakers, to achieve sustainable development.

Source: Prepared based on Apimondia, 2022.

indicators of climate trends and play a crucial role as bioindicators of the ecosystem and environmental degradation (Etxegarai-Legarreta and Sanchez-Famoso, 2022). Beekeeping also supports sustainable income growth for the rural poor. Vocational training in beekeeping creates equal opportunities for employment, education, extension, and entrepreneurship in the local community and beekeeping participation can increase women's opportunities for economic, social, and political decision-making. Apitourism, which supports nature-based tourism initiatives,

can also be promoted as sustainable tourism for regional development (Patel *et al.*, 2021; Apimondia, 2022).

The United Nations has issued a universal call to action to improve the lives of future generations through the 17 Sustainable Development Goals (SDGs) since January 2016 (Panta, 2020). Beekeeping is an activity that has the potential to positively impact all 17 SDGs, as it can improve food production systems ranging from traditional methods to highly advanced ones (Apimondia, 2022). The impact of beekeeping on SDGs is shown in Table 1. However, to fulfill the role of beekeeping in sustainable development, it is crucial to ensure the sustainability of beekeeping farms.

Beekeeping is a sector that has made significant progress in recent years, both in Turkey and around the world. The number of apiaries in Turkey increased by 6.74% in 2022 compared to the previous year, reaching 95,386 (Table 2). The number of hives also increased to 8,984,676 in 2022, showing a 2.88% increase compared to the previous year. Honey production in 2022 was 118,297 tons, which represents a significant increase of 22.79% compared to the previous year (TurkStat, 2023).

Turkey exported 17,248 tons of honey, generating 46,275 thousand dollars of foreign exchange revenue in 2022 (TurkStat, 2023). It is seen that the share of honey exports in the country's honey production was low from 2013 to 2020. However, in the last two years, 2021 and 2022, there has been some progress in export volumes (Table 3). Turkey also imports honey from time to time. In 2022, honey imports amounted to 58.24 tons, resulting in an expenditure of 163 thousand dollars of foreign exchange.

In recent years, the importance of crop products based on pollination by bees has increased worldwide. However, at the same time, the losses of bee colonies have also risen. A survey study, which involved 28,629 beekeepers from 35 different countries (31 EU member states), reported a general winter colony loss rate of 16.7% between countries for the 2018-2019 winter season, with the loss rate ranging from 5.8% to 32%. The highest loss rate was recorded in Slovenia with 32.0%, followed by Serbia with 25.4%, Spain, Croatia, Iran, Greece and Portugal with decreasing loss rates between 20% and 25%. The lowest loss rate was observed in Bulgaria, with a rate of 5.8% (Gray *et al.*, 2020). Studies conducted in different regions of Turkey determined that overwintering losses ranged from 9% to 36% (Sıralı and Doğaroğlu, 2005; Öztürk *et al.*, 2015; Emir,

Table 2 - Beekeeping statistics for Turkey (2013-2022).

Years	*Number of Beekeeping Farms*	*Total Number of Hives*	*Index*	*Honey Production (tons)*	*Index*	*Honey Production (kg/hive)*	*Index*
2013	79,934	6,641,348	100.00	94,694	100.00	14.26	100.00
2014	81,108	7,082,732	106.65	103,525	109.33	14.62	102.52
2015	83,475	7,748,287	116.67	108,128	114.19	13.96	97.90
2016	84,047	7,900,364	118.96	105,727	111.65	13.38	93.83
2017	83,210	7,991,072	120.32	114,471	120.89	14.32	100.42
2018	81,830	8,108,424	122.09	107,920	113.97	13.31	93.34
2019	80,675	8,128,360	122.39	109,330	115.46	13.45	94.32
2020	82,862	8,179,085	123.15	104,077	109.91	12.72	89.23
2021	89,361	8,733,394	131.50	96,344	101.74	11.03	77.36
2022	95,386	8,984,676	135.28	118,297	124.93	13.17	92.33
Average Annual Relative Change (%)	1.98	3.41	-	2.50	-	-0.88	-

Source: Calculated based on TURKSTAT, 2023.

Table 3 - Honey export-import in Turkey (2013-2022).

Years	*Amount of Export (ton)*	*Export Value (Thousand $)*	*Export Price ($/kg)*	*Export Amount/ Production Amount (%)*	*Import Value (Thousand $)*
2013	3,574	13,020	3.64	3.77	205
2014	4,972	18,934	3.81	4.80	184
2015	7,196	25,098	3.49	6.66	66
2016	3,628	14,953	4.12	3.43	64
2017	6,455	23,419	3.63	5.64	66
2018	6,418	25,691	4.00	5.95	150
2019	5,548	24,763	4.46	5.07	221
2020	6,038	26,161	4.33	5.80	294
2021	10,046	31,140	3.10	10.43	378
2022	17,248	46,275	2.68	14.58	163
Average Annual Relative Change (%)	19.11	15.13	-3.34	16.20	-2.49

Source: Calculated based on TURKSTAT, 2023.

2015). The decline in the number of bees poses a threat to the sustainability of beekeeping operations, as well as the sustainability of the agricultural system. This decline is likely to affect the production and cost of fruits and vegetables, leading to imbalanced and inadequate nutrition and health problems, particularly some non-communicable diseases (FAO, 2018). In addition to the loss of bee colonies, other factors such as habitat degradation, pollution, agricultural intensification and urbanization, diseases, allergies, pesticide residues, biodiversity decline, climate change, unconscious use of chemicals and antibiotics, and production focused on a single product, have contributed to the need for sustainable beekeeping practices. Sustainability practices on the farm are characterized by concern for environmental protection, respect for social equity, and ensuring the economic viability of the activity (Mokrani *et al.*, 2022).

2. Literature review

Agriculture, in general and beekeeping, in particular, emphasize the environmental, social, and economic pillars, the three dimensions of sustainability (Panta, 2020). Various studies have been conducted on the sustainability of beekeeping operations, examining different aspects of sustainability. Some studies have focused on evaluating one aspect of sustainability, such as cost analysis, carbon footprint, or Life Cycle Analysis (LCA) (Ćejvanović *et al.*, 2011; Kendall *et al.*, 2013; Strano *et al.*, 2015; Mujica *et al.*, 2016; Arzoumanidis *et al.*, 2019; Moreira *et al.*, 2019; Vásquez-Ibarra *et al.*, 2022; Pignagnoli *et al.*, 2021). Others have taken into account all three dimensions of sustainability, i.e., environmental, economic, and social aspects (Pocol *et al.*, 2012; Kouchner *et al.*, 2018; Rahimi *et al.*, 2020).

The indicators used to measure sustainability are directly related to the aspect of sustainability being addressed in each study. Ćejvanović *et al.* (2011) focused on the economic aspect of sustainability and suggested that income and income per hive are appropriate criteria for a sustainable beekeeping model. The economic aspect of sustainability was also highlighted in a study conducted by Strano *et al.* (2015). The results of this study, which evaluated the profitability of investments in apiculture farms in southern Italy using the Life Cycle Costing (LCC) method and economic indicators, showed a positive Net Present Value (NPV), a higher Internal Profitability Ratio (IRR) (5.26%) than the discount rate (r), and a Benefit-Cost ratio (B_0/C_0) of 1.13. These values indicate the profitabili-

ty of investment projects in beekeeping.

LCA has been widely used in studies of beekeeping sustainability towards the environment (Kendall *et al.*, 2013; Vásquez-Ibarra *et al.*, 2022). In the study by Kendall *et al.* (2013), the carbon footprint of honey production in the U.S. at various company sizes was estimated using LCA. The life-cycle modeling of a complete commercial supply chain (raw honey production, transport to a processor, and processing) showed that total greenhouse gas emissions ranged from 0.67 to 0.92 kg of CO_2 e/kg per kilogram of processed honey. A preliminary estimate of the global warming potential of honey production in Argentina was conducted by Mujica *et al.* (2016), and the carbon footprint of honey was estimated to be 2.5 ± 0.17 kg CO_2 e/kg honey. Moreira *et al.* (2019) conducted a study that evaluated the carbon footprint of honey production, and except for two producers, all achieved lower values than 1.66 kg CO_2 e/kg honey. The study suggests that various measures can be taken to reduce the environmental impacts associated with honey production, such as more efficient transportation, environmentally friendly packaging, and remote pest control systems that allow early detection of invasive wasps.

In the study conducted by Pignagnoli *et al.* (2021), the carbon footprints of migratory and stationary beekeeping were calculated to be 1.40 to 2.20 kg CO_2 e/kg honey and 0.380 to 0.48 kg CO_2 e/kg honey, respectively. In a study conducted in Chile, large-scale beekeepers produced an average of 0.26 kg CO_2 e/kg honey, medium-scale beekeepers 0.31 kg CO_2 e/kg honey, and small-scale beekeepers 0.85 kg CO_2 e/kg honey. The results of this study suggest that the environmental impact of honey production can be reduced through management practices focused mainly on feeding and transport (Vásquez-Ibarra *et al.*, 2022).

The study conducted in the northwestern region of Romania used both quantitative (questionnaire) and qualitative (focus group) research methods to explore several dimensions of beekeeping. The study found that beekeeping can be a profitable business, but its profitability is dependent on climatic conditions. Moreover, there is a lack of a strong system for promoting and marketing bee products in the study region. The study also highlighted the social and environmental benefits of beekeeping. From a social point of view, beekeeping supports rural development by creating job opportunities, while from an environmental perspective; beekeeping plays a critical role in pollination and biodiversity conservation (Pocol *et al.*, 2012).

Several studies have also explored the general framework of sustainability in beekeeping operations. For example, Panta (2020) aimed to identify value-adding activities in beekeeping operations from a sustainability perspective, while Kösoğlu *et al.* (2021) conducted a literature review to explore the concept of sustainability in beekeeping, considering factors such as bee health, environmental issues, climate change, and beekeeping practices. These studies emphasize the importance of strengthening awareness and legal measures to protect natural habitats, reducing environmental pollutants, and promoting the use of natural control methods against diseases and pests to ensure the sustainability of beekeeping and the production of high-quality bee products.

Over 120 agricultural sustainability assessment tools such as MESMIS (Framework for Assessing the Sustainability of Natural Resource Management Systems), RISE (Response-Inducing Sustainability Evaluation), SAFE (Sustainability Assessment of Farming and the Environment), IDEA (Indicateurs de Durabilité des Exploitations Agricoles), and SAFA (Sustainability Assessment of Food and Agriculture systems) are utilized to develop the indicators related to the economic, environmental and social dimensions of sustainability. (Lopez-Ridaura *et al.*, 2002; Hani *et al.*, 2003; Van Cauwenbergh *et al.*, 2007; Zahm *et al.*, 2008; FAO, 2012; Talukder and Blay-Palmer, 2017). For instance, Kouchner *et al.* (2018) developed a sustainability framework based on a participatory approach to suit the specificities of beekeeping in France. The SAFA guide was used as a basis for the study, which resulted in six dimensions and 15 themes that can be used to assess the sustainability of beekeeping operations. These dimensions include the beekeeping sector and society issues,

economic viability, environmental impacts, development, and the ability to ensure production and quality of life. In another study conducted in Iran, the Delphi technique was used to determine the sustainability criteria of the beekeeping sector. The opinions of 32 experts were gathered, resulting in the identification of 13 sustainability criteria (Rahimi *et al.*, 2020).

Despite the multitude of methodologies and frameworks for assessing sustainability, there is currently no consensus on the widespread use of one methodology, and various frameworks and indicators are still being utilized (Abdollahzadeh *et al.*, 2015). Given the significant differences in management practices between professional beekeeping and other agricultural activities, it is not appropriate to apply a sustainability assessment tool developed for other agricultural activities directly to beekeeping (Kouchner *et al.*, 2018). Therefore, this study aims to develop an index to measure sustainability in beekeeping at the farm level in Aydın, İzmir, and Muğla provinces in the Aegean region of Turkey and to provide recommendations for future research based on the developed index.

3. Materials and method

3.1. *Research area*

This study was conducted in the provinces of Aydın, İzmir, and Muğla, located in the Aegean region of Turkey (Figure 1). These provinces have a Mediterranean climate, with hot and dry summers and warm and rainy winters (MGM, 2022a). According to long-term data from 1941 to 2021, the average temperatures in these provinces are 17.7°C, 17.9°C, and 15.1°C, respectively. The annual average number of rainy days is 81.9, 84.2, and 108.9, respectively, and the average annual precipitation is 661.7 mm/year, 713.8 mm/year, and 1209.1 mm/year, respectively (MGM, 2022b).

3.2. *Sampling method*

The data for this study were collected through questionnaires from 149 apiaries located in the provinces of Aydın, İzmir, and Muğla in the Aegean region. The main population of the survey consisted of 8,508 apiaries registered in the Apiculture Registration System (AKS) in these provinces. The sample size of 149 producers

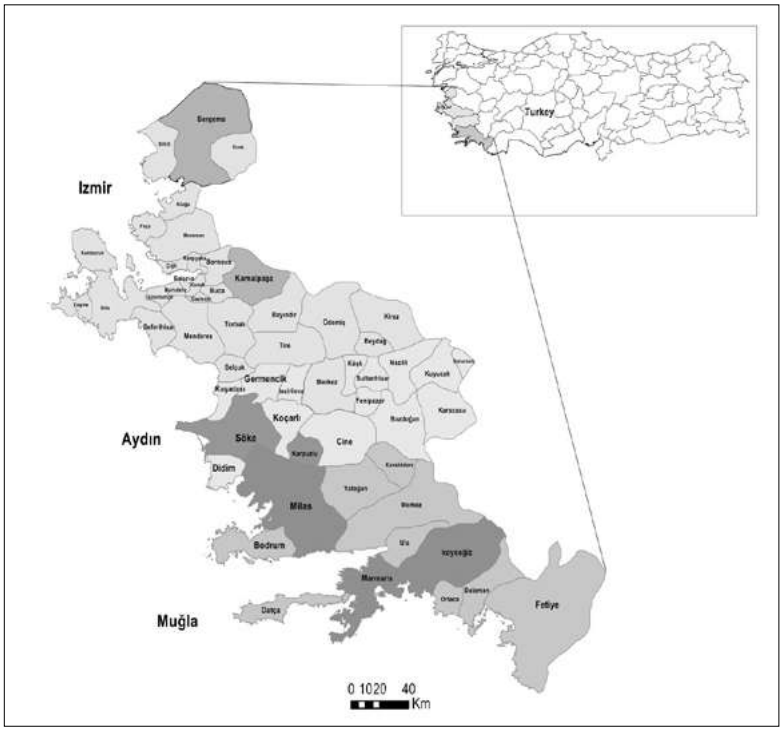
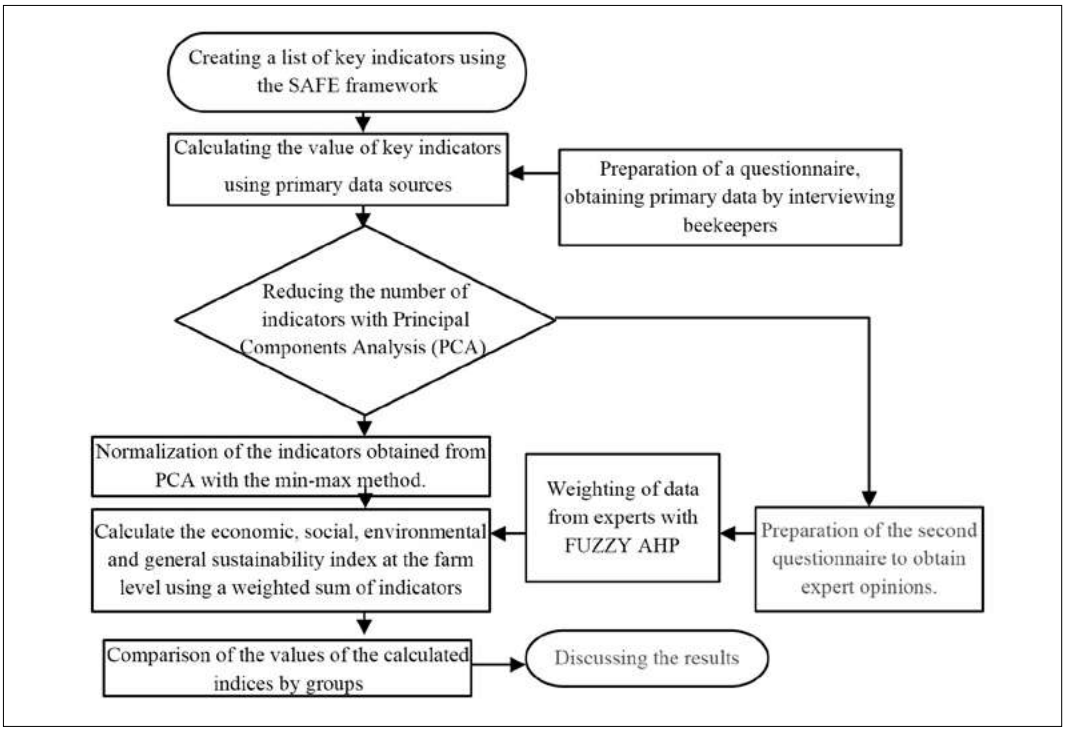


Figure 1 - Location map of the studied area constructing by ArcGIS.

Figure 2 - The methodology used in the research.



was determined using the proportional sample size formula (Newbold, 1995), with a 95% confidence interval and a margin of error of 8%.

$$n = \frac{N.p(1-p)}{(N-1)\sigma_{p_x}^2 + p(1-p)} \quad (1)$$

Where n as sample size and N as the number of beekeepers in the study area, $\sigma_{p_x}^2$ shows the variance and p represents the ratio of producers adopting sustainable practices in beekeeping (the ratio of producers adopting sustainable practices in beekeeping to reach the maximum sample size was assumed to be 0.50). The number of producers to be interviewed in each province was determined by considering the total number of producers in the provinces. Thus, 82 producers were interviewed in Muğla, 37 in İzmir, and 30 producers in Aydın.

The districts selected for study in each province were those with intensive honey production. According to 2018 data, Milas, Köyceğiz, and Marmaris districts account for 49.36% of the total honey production in Muğla, while Söke and Karpuzlu districts account for 52.12% of the total honey production in Aydın, and Bergama and Kemalpaşa districts account for 46.76% of the total honey production in İzmir. The number of producers surveyed in each district was determined based on the ratio of districts to the total number of producers. As a result, 36 producers were surveyed in Milas, 26 in Köyceğiz, 20 in Marmaris, 23 in Bergama, 14 in Kemalpaşa, 16 in Karpuzlu, and 14 in Söke. The producer interviewed in each district was chosen randomly.

3.3. *Developing the sustainability index*

Tomeasure the sustainability level of beekeeping farms, a composite sustainability index was calculated while taking into account the recommendations of OECD (2008). Figure 2 shows the methodology used in the study.

To select key sustainability indicators in the first stage, the SAFE method was used. The SAFE framework aims to assess sustainability in agriculture progressively by defining principles, criteria, and indicators (Van Cauwenbergh *et al.*, 2007). The study implemented criteria and indi-

Table 4 - Indicators for sustainable beekeeping.

Indicators and descriptions	
1. Economic	
Gross production value	Value of products such as honey, pollen, etc., produced in the hive, bee sales, government support, and pollination income. (TL)
Net profit	Net profit per hive. It is calculated by subtracting production costs from gross production value. (Excluding the provision of family labor) (TL)
Gross profit	Gross profit per hive. It is calculated by subtracting variable costs from gross production value. (TL)
Relative profit	Gross production value obtained in relation to the unit cost. (ratio)
Honey yield	Amount of honey produced per hive (kg)
Labor profitability	Net profit per employee (TL)
Risk management with diversification	The production of various bee products with high added value as risk management in the apiary (Likert). - According to the assessment of producers, the degree of effectiveness of the expression "Production of bee products other than honey" as a risk management strategy; (*1=not at all effective, 2=ineffective, 3= somewhat effective, 4=very effective, 5=extremely effective).*
Willing to diversification	Willingness to produce other hive products besides honey, such as pollen, propolis, royal jelly, bee bread, and bee venom in beekeeping (Likert). - The degree of agreement of producers to the statement "Besides honey in beekeeping, I also consider the production of other hive products with high economic value"; *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*
2. Social	
Beekeeper's accommodation	The place where the beekeeper stays to carry out the beekeeping activity (categorical) *(1= tent or shed in the apiary, 2=caravan, 3=car, 4=village houses, 5=Rent house, 6=hotel near the hive, 7=self-built house, 8= returnee without accommodation, 9= stationary beekeeper).*
Time away from home	The time that the beekeeper is separated from his family members to carry out the beekeeping activity (categorical) *(1= More than 3 months, 2= 1-3 months, 3= Less than 1 month, 4= They go with the family, 5= stationary beekeeper)*
Transportation distance	The transport of hives in their ecological environment, is an indicator that influences the welfare of bees (categorical) *(1=more than 1854 km, 2=1136-1854 km, 3=415-1135 km, 4= less than 415 km)*
Working period in beekeeping	The time the beekeeper and his family worked in the apiary (hours)
Employment	Employment created by beekeeping (person)
Satisfaction with education and health services	Degree of producer agreement with the statement "I am satisfied with the services provided by schools and health centers in my region." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*
Access to social and cultural spaces	Degree of agreement of the producer to the statement "In my region, there are social and cultural areas." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*

3. Environmental (shows the beekeeper's attitude towards the environment)	
Environment for health	Environmental protection tendency of beekeepers to produce healthy bee products (Likert) -Degree of agreement of the producer to the statement "I protect nature for the production of healthy bee products." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*
Environment for sustainable production	Environmental protection tendency of the beekeeper for the ability to do beekeeping in the future (Likert) - Degree of agreement of the producer to the statement "I protect nature to be able to do beekeeping in the future." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*
Forest protection	The tendency of the beekeepers to protect the forest (Likert) - Degree of producer agreement with the statement "beekeepers are conscious about forest protection." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*
Conserving biodiversity	The opinion of beekeepers about the role of bees in the protection of biodiversity (Likert) - Degree of producer agreement with the statement "The honey bee is of great importance for biodiversity and a sustainable environment." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*

cators for each principle of sustainability based on the SAFE framework. After selecting the basic sustainability indicators, their value was calculated using the primary data sources obtained from the survey conducted with beekeepers.

In the second stage, Principal component analysis (PCA) was used as a data preparation technique to reduce the dimension and eliminate the dependency structure between indicators. Table 4 shows the characteristics of the indicators obtained from PCA analysis.

As the indicators and units of measurement used in this study differ from each other, the min-max method was used in the third stage (Freudenberg, 2003) to assign a value of 0 to the smallest indicator value and a value of 1 to the largest. This method eliminates scale errors caused by different units of measurement.

In the fourth stage, weighting was performed to determine the relative importance of the selected key indicators. Weighting techniques to create an index can be categorised as "positive" or endogenous, and "normative" or exogenous (Gómez-Limón and Sanchez-Fernandez, 2010). Positive or endogenous techniques allow obtaining weights of key indicators through statistical procedures, while normative or exogenous techniques attempt to assign different weights to indicators depending on the opinion of experts and external decision-makers (Fallah-Alipour *et al.*, 2018). The Fuzzy Analytic Hierarchy Process (Fuzzy AHP) proposed by Chang (1996) was used in the study to weight the main sustainability indicators and incorporate experts' opinions into the analysis (Pala, 2016). The experts whose opinions were incorporated into the study consisted of faculty members who are experts in beekeeping, faculty members from the departments of agricultural economics who work in beekeeping and sustainable agriculture, expert agricultural engineers who work in the beekeeping department of the Agricultural Research Institute, forestry engineers, university students who research beekeeping and sustainable agriculture, and conscious beekeepers.

The weighted sum of indicators in Stage 5 was used to create the composite index of economic, social, environmental, and overall sustainability (Fallah-Alipour *et al.*, 2018).

$$KE = \sum_{k=1}^{k=n} W_k^* . I_k \qquad (2)$$

Table 5 - Categories of the farms by their production diversity.

Categories	*Number of Farms*	*%*	*Average Number of Hives*
Single-product farms	66	44.30	250.38
Diversified farms	83	55.70	305.80
Total	149	100.00	281.25

Table 6 - Grouping of the farms due to locations.

Provinces	*Number of Farms*	*%*	*Average Number of Hives*
Aydın	30	20.13	282.60
İzmir	37	24.83	231.51
Muğla	82	55.04	303.20
Total	149	100.00	281.25

Where KE is agricultural sustainability index derived from n indicators, I_k as the normalized value of the indicator and W_k^* is the standard weight of the indicator.

The study regions were compared and classified into relative sustainability levels for economic, social, and environmental dimensions, as well as an overall agricultural sustainability status, based on the results of the composite indices obtained. To accomplish this, the standard deviation range from the mean was utilized.

In addition, the farms were grouped in two different ways and their sustainability levels were compared according to these groups. In the first grouping, the product diversity of the farms was taken into account and the farms were divided into two categories: the first category was farms producing only honey and beeswax (single-product farms), and the second category was farms producing both honey and beeswax and at least one other bee product (diversified farms) (Table 5). The second grouping took into account the provinces where the farms are located (Table 6).

4. Result and discussion

4.1. *General situation of apiaries*

The average age of producers was 50.11 years, the average period of education was 6.31 years, the average farming experience of farmers was 32.14 years, and the average beekeeping experience was 25.15 years (Table 7). These values are similar to the results of other studies. In stud-

Table 7 - The average age, education level and experience of beekeepers.

Characteristics	*Categories*			*Provinces*				*General (149)*
	Single-product farms (66)	*Diversified farms (83)*	*p*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	*p*	
Age	52.14	48.51	0.06	49.97	51.05	49.74	0.85	50.11
Duration of Education (year)	5.92	6.61	0.03**	6.40	5.95	6.44	0.45	6.31
Agricultural Experience (year)	33.39	31.02	0.38	31.94	32.21	32.19	0.98	32.14
Beekeeping Experience (year)	24.89	25.36	0.67	21.75	24.70	26.60	0.16	25.15

*(*p<0.05; **p<0.01; ***p<0.001 significant level).*

Table 8 - The household size of the farms.

	Categories			*Provinces*				*General (149)*
	Single-product farms (66)	*Diversified farms (83)*	*P*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	*p*	
Male	2.02	2.07	0.71	2.20	1.81	2.10	0.09	2.05
Female	1.65	1.80	0.38	1.90	1.62	1.72	0.41	1.73
Total	3.67	3.87	0.38	4.10	3.43	3.82	0.14	3.78

ies conducted in different provinces of Turkey, it was found that the average age of beekeepers ranges from 40.85 to 54.71 years, the average period of education ranges from 5.68 to 9.28 years, and the average experience of beekeepers ranges from 11.08 to 23 years (Saner *et al.*, 2005; Ören *et al.*, 2010; Saner *et al.*, 2011; Emir, 2015; Çevrimli, 2017; Subaşı *et al.*, 2019; Onuç *et al.*, 2019; Aydın *et al.*, 2020).

The average household size was 3.78. The average number of males was 2.05 and the number of females was 1.73 (Table 8).

In 41.61% of the studied farms there are 1-200 hives, in 28.86% 201-350 hives and in 29.53% more than 350 hives (Table 9). In the study conducted in the Mediterranean region, the average number of hives was 179.06 (Subaşı *et al.*, 2019).

Upon analysis of the sub-indicators used to measure sustainability in the studied provinces, it was found that 30.00%, 43.24%, and 50.00% of farms in Aydın, İzmir, and Muğla provinces respectively, produced only honey and beeswax. Similar findings were reported in a study conducted in Kütahya province, where 67.2% of beekeepers produced honey only, 30.3% produced pollen, 0.5% produced royal jelly, and 22% produced beeswax (Özer, 2017). The honey yield per hive in Aydın, İzmir, and Muğla provinces were calculated to be 12.50 kg, 21.25 kg, and 15.84 kg, respectively (Table 10). In another study conducted in the Aegean Region, honey yield in apiaries with different hives varied between 11.4 kg and 21.4 kg (Koç and Karacaoğlu, 2016).

The gross production value per hive in these provinces was calculated as 236.15 TL, 352.64 TL, and 252.45 TL, respectively (Table 11). According to the results of the Kruskal-Wallis test, there was a statistically significant difference between the provincial groups ($\chi 2=14.08$, $p=0.00$). Gross profit was calculated as 136.22 TL, 246.57 TL, and 123.24 TL, respectively. It is noteworthy that farms in Aydın and Muğla had a negative net profit, while farms in İzmir had a positive net profit. In the relative profit analysis, the farms in Aydın produced 0.96 value units for every 1 cost unit, the farms in İzmir produced 1.28 value units for every 1 cost unit, and the farms in Muğla

Table 9 - Distribution of farms by the number of hives.

	Categories				*Provinces*							
	Single-product farms (66)		*Diversified farms (83)*		*Aydın (30)*		*İzmir (37)*		*Muğla (82)*		*General (149)*	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
1-200 hives	31	46.97	31	37.34	14	46.66	23	62.16	25	30.49	62	41.61
201-350 hives	17	25.76	26	31.33	5	16.67	7	18.92	31	37.8	43	28.86
350+ hives	18	27.27	26	31.33	11	36.67	7	18.92	26	31.71	44	29.53
Total	66	100.00	83	100.00	30	100.00	37	100.00	82	100.00	149	100.00

Table 10 - Efficiency of bee products in farms.

	Categories			*Provinces*				*General (149)*
	Single-product farms (66)	*Diversified farms (83)*	*P*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	*p*	
Honey (kg/hive)	15.20	17.55	0.20	12.50	21.25	15.84	0.00**	16.51
Beeswax (gr/hive)	306.30	392.70	0.19	302.85	295.55	399.89	0.17	354.40
Pollen (gr/hive)	-	486.10	-	794.20	473.19	382.73	0.56	486.10
Propolis (gr/hive)	-	18.03		7.17	23.01	18.18	0.37	18.03
Bee bread (gr/hive)	-	133.73		-	-	133.73		133.73

*(*p<0.05; **p<0.01; ***p<0.001 significant level).*

Table 11 - Annual operating results in farms (per hive).

	Categories		*Provinces*			*General (149)*
	Single-product farms (66)	*Diversified farms (83)*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	
Gross production value (TL)	*227.99*	*310.67*	*236.15*	*352.64*	*252.45*	*274.05*
Variable costs (TL)	117.44	117.67	99.93	106.07	129.21	117.58
Fixed costs (TL)	154.67	143.91	145.67	168.63	140.78	148.68
Production costs (TL)	*272.11*	*261.58*	*245.60*	*274.70*	*269.99*	*266.26*
Gross profit	110.55	193.00	136.22	246.57	123.24	156.47
Net profit	-44.12	49.09	-9.45	77.94	-17.54	7.79
Relative Profit	0.84	1.19	0.96	1.28	0.94	1.03

province produced 0.94 value units for every 1 cost unit. Previous studies conducted in the Mediterranean region reported a relative profit of 2.70, while a study conducted in Gökçeada, Çanakkale, reported a relative profit rate of 2.28 (Öztürk *et al.*, 2015; Subaşı *et al.*, 2019; Özyasin and Karaman, 2018).

When the farms were investigated in terms of employment, it was found that 273.08 male working days (MWD) were spent on beekeeping activities on farms in Aydın, 273.51 MWD on farms in İzmir, and 312.97 MWD on farms in Muğla (Table 12). In a study conducted by Onuç *et al.* (2019) in the Kemalpaşa district of İzmir province, the total workforce used in beekeeping was reported as 224.64 MWD (Onuç *et al.*, 2019).

Regarding the type of beekeeping, it was found that 70.00%, 75.68%, and 98.78% of producers in Aydın, İzmir, and Muğla provinces, respectively, were interregional migratory beekeepers (Table 13). The highest number of stationary beekeepers was found in Aydın province, the highest number of intra-provincial migratory beekeepers in İzmir province, and the highest number of inter-regional migratory beekeepers in Muğla province. In a study conducted in Çanakkale province, 87.36% of

Table 12 - Labor use in farms (MWD).

	Categories			*Provinces*				
	Single-product farms (66)	*Diversified farms (83)*	*p*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	*p*	*General (149)*
Family labor use	253.8	276.52	0.53	243.92	249.7	282.27	0.16	266.46
Temporary labor use	21.36	34.51	0.07	29.17	23.81	30.71	0.64	28.68
Total labor use	275.16	311.03	0.28	273.08	273.51	312.97	0.21	295.14

Table 13 - Beekeeping systems of farms.

	Categories				*Provinces*							
	Single-product farms (66)		*Diversified farms (83)*		*Aydın (30)*		*İzmir (37)*		*Muğla (82)*		*General (149)*	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Stationary	3	4.55	4	4.82	4	13.33	2	5.40	1	1.22	7	4.70
Intra-provincial	4	6.06	8	9.64	5	16.67	7	18.92	-	-	12	8.05
Interregional migratory	59	89.39	71	85.54	21	70.00	28	75.68	81	98.78	130	87.25
Total	66	100.00	83	100.00	30	100.00	37	100.00	82	100.00	149	100.00

beekeepers practiced migratory beekeeping, while 12.64% practiced stationary beekeeping (Aktürk and Aydın, 2019).

The average number of hive accommodation places on farms located in Aydın, İzmir, and Muğla provinces was calculated as 3.03, 3.49, and 3.52, respectively, while the total transport distance per farm was calculated as 939.63 km, 644.97 km, and 1426.70 km, respectively (Table 14). According to the results of the Kruskal-Wallis test, the differences between provincial groups in terms of distance ($\chi 2=36.831$, $p=0.000$) were found to be statistically significant. In a study conducted in Muğla, Denizli, and Aydın provinces, the average number of hive accommodation places was calculated to be 3.9, and the average transport distance was calculated to be 769 km (Çevrimli, 2017).

In Aydın, İzmir, and Muğla provinces, 70.00%, 59.46%, and 90.24% of producers, respectively, live in tents and huts on the apiary, while 30.00%, 13.51%, and 2.44% of them finish their work without accommodation and return. Additionally, it was found that 30.00%, 16.21%, and

Table 14 - The average number of hive accommodation places in the farms.

		Categories			*Provinces*				*General (149)*
		Single-product farms (66)	*Diversified farms (83)*	*P*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	*p*	
number of hive accommodation	Max	6	8		6	6	8		8
	Min	1	1		1	1	1		1
	Average	3.08	3.69	0.01*	3.03	3.49	3.52	0.31	3.42
Total transport distance (KM)		1132.92	1135.78	0.87	939.63	644.97	1426.70	0.00**	1134.51

*(*p<0.05; **p<0.01; ***p<0.001 significant level).*

Table 15 - Working conditions of beekeepers in the farms.

		Categories				*Provinces*						*General (149)*	
		Single-product farms (66)		*Diversified farms (83)*		*Aydın (30)*		*İzmir (37)*		*Muğla (82)*			
		N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Accommodations	tent/ hut in apiary	55	83.33	62	74.70	21	70.00	22	59.46	74	90.24	117	78.52
	finishes her work and returns	6	9.09	10	12.05	9	30.00	5	13.51	2	2.44	16	10.74
	Other	5	7.58	11	13.25	0	0.00	10	27.03	6	7.32	16	10.74
	Total	*66*	*100.00*	*83*	*100.00*	*30*	*100.00*	*37*	*100.00*	*82*	*100.00*	*149*	*100.00*
Away from family members	less than 1 month	17	25.76	17	20.48	11	36.67	13	35.14	10	12.20	34	22.82
	1-3 months	23	34.85	29	34.94	10	33.33	18	48.65	24	29.27	52	34.90
	more than 3 months	26	39.39	37	44.58	9	30.00	6	16.21	48	58.53	63	42.28
	Total	*66*	*100.00*	*83*	*100.00*	*30*	*100.00*	*37*	*100.00*	*82*	*100.00*	*149*	*100.00*

58.53% of the producers on farms in these provinces, respectively, live away from their family members for more than 3 months a year to do beekeeping (Table 15).

4.2. *Assessment of sustainability levels in the farms*

Principal component analysis (PCA) was utilized to determine the sustainability levels if there was a significant correlation among the selected key indicators and to group them into statistically similar indicator groups, making interpretation easier. The appropriateness of the data for PCA analysis was determined by the KMO and Bartlett test statistics (Table 16).

The results indicated a strong correlation between the indicators that were implemented in the model, which was confirmed through PCA analysis.

A total of 80.92% of the cumulative variance in the indicators can be explained by 7 components, as shown in Table 17. Components 1 and 5 reflect the economic sustainability of the beekeeping farms, and are related to factors such as profitability, financial stability, risk management, and production diversity. Components 2, 3, and 6 represent the social sustainability of beekeeping activities, and are based on factors such as the health and well-being of bees and beekeepers, the potential for job creation through beekeeping, and the ability of beekeepers to access social opportunities.

Components 4 and 7 are indicative of environmental sustainability and reflect the beekeeper's attitude toward the environment. Once the sub-indicators were obtained through PCA analysis, each sub-indicator value was standardized using the min-max method.

The weighting of each indicator resulting from the PCA method was determined using the Fuzzy AHP method in order to calculate the composite sustainability index. The hierarchical structure for this process is illustrated in Figure 3.

A questionnaire was created with indicators to determine the weight of sustainable beekeeping

Table 16 - KMO and Bartlett test results.

Kaiser-Meyer-Olkin (KMO) Test for Sampling Adequacy		0.711
Bartlett's Test of Sphericity	Approximate Chi-Square	3015.408
	Degrees of Freedom	171
	Significance Level	0.000

Table 17 - Principal component loads and related oriented indicator.

Rotated Component Matrix							
	Components						
	1	*2*	*3*	*4*	*5*	*6*	*7*
Net profit	**0.985**	-0.015	0.082	0.018	-0.017	0.040	0.000
Gross profit	**0.984**	-0.011	0.085	0.017	-0.014	0.046	-0.001
Gross production value	**0.936**	-0.148	0.120	0.055	0.033	0.063	-0.015
Relative profit	**0.867**	0.213	0.017	-0.017	-0.029	0.033	0.003
Honey yield	**0.864**	-0.201	0.144	0.072	-0.006	0.080	-0.015
Labor profitability	**0.765**	0.060	-0.348	-0.009	-0.039	-0.039	0.028
Beekeeper's accommodation	0.018	**0.840**	-0.097	-0.037	-0.048	0.042	-0.050
Time away from home	-0.034	**0.805**	0.035	-0.119	0.037	0.131	0.000
Transportation distance	-0.050	**0.784**	-0.118	-0.172	-0.130	-0.171	0.083
Working period in beekeeping	0.037	-0.054	**0.966**	0.084	-0.067	-0.013	-0.022
Employment	0.105	-0.101	**0.965**	0.075	-0.035	-0.010	-0.011
Environment for health	0.062	-0.130	0.071	**0.965**	-0.017	0.043	-0.025
Environment for sustainable production	0.016	-0.175	0.088	**0.956**	0.027	0.054	0.039
Risk management with diversification	-0.137	0.022	-0.055	-0.030	**0.846**	0.002	-0.168
Willing to diversification	0.078	-0.130	-0.048	0.031	**0.838**	-0.081	0.162
Satisfaction with education and health services	0.026	-0.147	0.049	0.112	-0.095	**0.826**	0.032
Access to social and cultural spaces	0.107	0.182	-0.068	-0.023	0.023	**0.783**	0.045
Forest protection	-0.077	0.118	-0.198	-0.127	-0.252	-0.054	**0.715**
Conserving biodiversity	0.069	-0.101	0.167	0.154	0.269	0.167	**0.689**

Figure 3 - Hierarchical structure in relation to the sustainability of beekeeping operations.

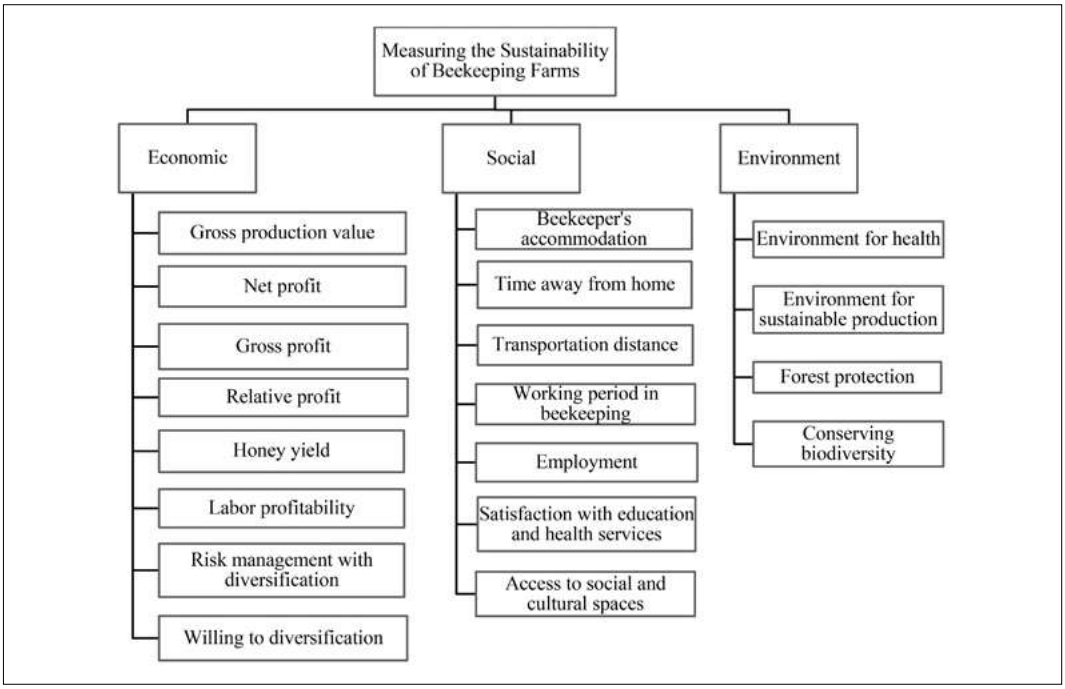


Table 18 - Weighting of the three dimensions of sustainability with the Fuzzy AHP method.

Criteria	*Standardized Weight*	*Rank*
Economic	0.346	1
Environmental	0.332	2
Social	0.321	3

CR (Consistency Ratio: 0.065).

dimensions, which was sent to experts. The questionnaire assessed the importance of each criterion relative to others, assigning values from 1 to 9. The scores obtained from 12 subject matter experts were first blurred and then the geometric mean of the fuzzy scores was taken to obtain a fuzzy pairwise comparison matrix for the main criteria and sub-criteria. Using these values, the weight of the three basic dimensions of sustainable beekeeping (economic, social, and environmental) and their corresponding indicators were calculated. The economic criterion was found to be the most important, with a weight value of 0.346 (Table 18). This was followed by the environmental criteria with a weighting value of 0.332 and the social criteria with a weighting value of 0.321. The consistency ratio of the criteria was calculated to be 0.065, which is below 10%, indicating that the created pairwise comparison matrix is consistent.

Interpretation of the results revealed that the most important sub-criterion of the economic criterion is net profit with a weighting value of 0.127, the most important sub-criterion of the social criterion is employment with a weighting value of 0.146, and the most important sub-criteria of the environmental criteria are environmental protection tendency of the beekeeper for the ability to do beekeeping in the future and the beekeeper's opinion of beekeepers about the role of bees in the protection of biodiversity (Table 19).

The consistency ratio for the sub-criteria re-

Table 19 - Weighting of the sustainability indicators with the Fuzzy AHP method.

Sub-Criteria		*Within criteria*		*Compound of criteria*	
		Weight	*Rank*	*Weight*	*Rank*
Econ. (CR=0.004)	Net profit	0.127	1	0.0439	11
	Labor profitability	0.126	2	0.0436	12
	Relative profit	0.125	3	0.0433	13
	Honey yield	0.125	3	0.0433	13
	Risk management with diversification	0.125	3	0.0433	13
	Gross profit	0.124	4	0.0429	14
	Willing to diversification	0.124	4	0.0429	14
	Gross production value	0.123	5	0.0426	15
Soc. (CR= 0.061)	Employment	0.146	1	0.0469	4
	Satisfaction with education and health services	0.145	2	0.0465	5
	Transportation distance	0.144	3	0.0462	6
	Working period in beekeeping	0.143	4	0.0459	7
	Beekeeper's accommodation	0.142	5	0.0456	8
	Access to social and cultural spaces	0.141	6	0.0453	9
	Time away from home	0.140	7	0.0449	10
Env. (CR=0.002)	Environment for sustainable production	0.252	1	0.0837	1
	Conserving biodiversity	0.252	1	0.0837	1
	Forest protection	0.250	2	0.0830	2
	Environment for health	0.247	3	0.0820	3

Table 20 - Sustainability index values of beekeeping farms.

Composite Sustainability Index	*Minimum*	*Maximum*	*Average*
Economic Sustainability Index	0.09	0.87	0.45
Social Sustainability Index	0.08	0.99	0.36
Environmental Sustainability Index	0.50	1.00	0.92
General Sustainability Index	0.36	0.83	0.58

lated to the economic, social, and environmental criteria was calculated as 0.004, 0.061, and 0.002, respectively. These results indicate that the pairwise comparison matrix created for the sub-criteria is consistent (Table 19).

The fact that the consistency ratios for all sub-criteria are less than 10% indicates that the pairwise comparison matrix created for the sub-criteria is consistent (Table 19). Afterward, the economic sustainability index, social sustainability index, environmental sustainability index, and general sustainability index of beekeeping farms were calculated using the normalized values and standard weights of the basic indicators. The calculated sustainability index values range from 0 to 1, with values closer to 1 indicating a more sustainable system.

The economic sustainability index was calculated to be 0.45, the social sustainability index as 0.36, the environmental sustainability index as 0.92, and the general sustainability index as 0.58 for the farms that were investigated. Given that many of the traditional criteria used to evaluate environmental sustainability are not applicable to the beekeeping sector, the study measured the attitudes of beekeepers towards the environment as a means of assessing environmental sustainability. The fact that this value is high indicates that beekeepers in the study region are sensitive to environmental protection (Table 20). This finding is similar to the results of other studies. According to the study conducted by Hayran *et al.* (2018) in Mersin province, Turkey, farmers show great interest in preserving natural resources for future generations.

A reference table was created by using the average value and standard deviation of the general sustainability index of beekeeping farms to make comparisons between different groups of farms (Table 21).

Table 21 - The reference values for the general sustainability of beekeeping operations.

Category	*Score*	*Range*
Not sustainable	A	0.00-0.49
Relatively unsustainable	B	0.50-0.58
Relatively sustainable	C	0.59-0.65
Sustainable	D	0.64-1.00

A study on groups of farms that diversified their production found that farms producing other bee products in addition to honey are more sustainable than those focusing solely on honey. This was evident from the economic, social, and environmental sustainability indices and the overall sustainability index (sustainability level C). The Mann-Whitney U-test revealed that the difference between the two groups was statistically significant for both the economic sustainability index (Mann-Whitney U=1863.00, p=0.001) and the general sustainability index (Mann-Whitney U=2175.00, p=0.031) (Table 22).

In terms of economic sustainability, İzmir ranked first with an index value of 0.49, followed by Muğla Province with an index value of 0.44 and Aydın Province with an index value of 0.43 in third place. Aydın and İzmir provinces ranked first in the social sustainability index with an index value of 0.41, followed by Muğla with an index value of 0.32. In terms of environmental sustainability, İzmir ranked first with an index value of 0.95, followed by Muğla Province with an index value of 0.93 and Aydın Province with an index value of 0.85.

The general sustainability index of İzmir Province ranked first (sustainability level C), while Aydın and Muğla provinces were tied for second (sustainability level B) (Table 22). The Kruskal-Wallis test indicated that the dif-

Table 22 - Sustainability index values by farm groups.

Farm Groups		*Econ. S. Index*	*p value*	*Soc. S. Index*	*p value*	*Env. S. Index*	*p value*	*General S. Index*	*p value*	*General S. rank*
Categories	Single-product farms (66)	0.41	0.001**	0.35	0.227	0.93	0.382	0.56	0.031*	B
	Diversified farms (83)	0.48		0.37		0.92		0.59		C
Provinces	Aydın (30)	0.43	0.072	0.41	0.001**	0.85	0.001**	0.56	0.001**	B
	İzmir (37)	0.49		0.41		0.95		0.62		C
	Muğla (82)	0.44		0.32		0.93		0.56		B
General		0.45	-	0.36	-	0.92	-	0.58	-	-

*A: Not sustainable, B: Relatively unsustainable, C: Relatively sustainable, D: Sustainable (*p<0.05; **p<0.01; ***p<0.001 significant level).*

Table 23 - General sustainability levels of beekeeping farms.

Category	*Aydın (30)*		*İzmir (37)*		*Muğla (82)*		*General (149)*	
	count	*%*	*count*	*%*	*count*	*%*	*count*	*%*
Not sustainable (A)	8	26.67	0	0.00	14	17.07	22	14.77
Relatively unsustainable (B)	9	30.00	15	40.54	34	41.46	58	38.93
Relatively sustainable (C)	10	33.33	9	24.32	25	30.49	44	29.53
Sustainable (D)	3	10.00	13	35.14	9	10.98	25	16.78
Total	30	100.00	37	100.00	82	100.00	149	100.00

ference between the provincial groups was statistically significant in the social sustainability index ($\chi2$=13.45, p=0.001), environmental sustainability index ($\chi2$=13.11, p=0.001), and general sustainability index ($\chi2$=13.06, p=0.001) (Table 22).

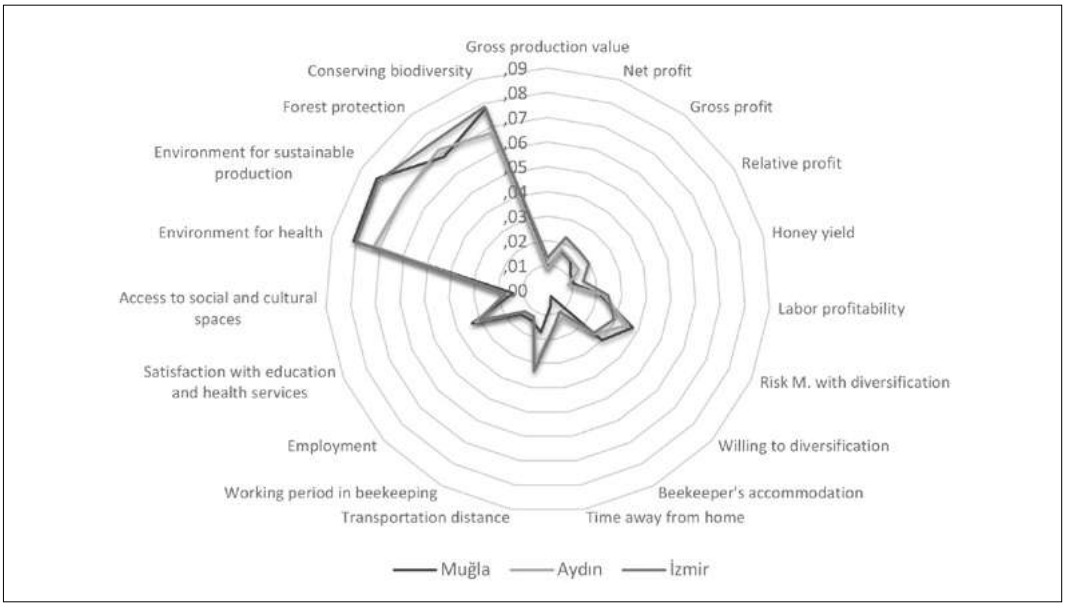
The study shows that 14.77% of beekeepers' activities were not sustainable, and 38.93% were threatened and relatively unsustainable. The activities of 29.53% of beekeepers were relatively sustainable, while 16.78% were sustainable. The beekeeping activities in Aydın, İzmir, and Muğla were relatively sustainable (C) and sustainable (D) for 43.33%, 59.46%, and 41.46% of beekeepers, respectively (Table 23). The study suggests that restricting beekeepers to migratory beekeeping in their regions and improving different ecotypes in geographical regions and making them available to beekeepers could promote the sustainability of beekeeping (Kösoğlu *et al.*, 2017).

The status of general sustainability in relation to the basic indicators in the provinces studied is shown in Figure 4.

5. Conclusion

Beekeeping is a multifaceted activity that plays an important role in social, economic, and environmental aspects and contributes significantly to natural ecosystems. Effective beekeeping practices and colony management are critical factors in ensuring the success and sustainability of beekeeping operations. This study focuses on evaluating the various interrelated dimensions of sustainability in beekeeping farms located in the Aydın, İzmir, and Muğla provinces of the Aegean region, with a specific emphasis on beekeeping practices. In this research, which was conducted using data from a total of 149 beekeeping farms, including 30 in Aydın, 37 in İzmir and 82 in Muğla, evaluations and analyzes were made in relation to the production diversity of the farms and the provinces in which they are located.

Figure 4 - The status of general sustainability by the basic indicators in the provinces.



According to the results, beekeeping farms that have integrated production diversity practices are more sustainable, both economically and in terms of overall sustainability, than those that solely focus on honey production.

Beekeeping operations can reduce price and production risks by diversifying their production, transitioning from a single-product, low-yield production model to a diversified beekeeping model that includes high-value-added products such as pollen, propolis, royal jelly, bee venom, perga, and apilarnil. This practice can promote more sustainable beekeeping. However, on farms that focus exclusively on honey production, beekeeping often takes the form of a unified production and livelihood. This narrow focus on honey can lead to a disregard for bee health and product safety, as beekeepers prioritize increasing honey production at the expense of other factors. Therefore, diversifying production is essential to achieve sustainable beekeeping practices that consider the bees' health and well-being, as well as the quality and safety of the products they produce.

In terms of economic sustainability, İzmir ranks first, followed by Muğla in second place and Aydın in third place. However, the differences between their values are relatively small. In terms of the sub-indicators of economic sustainability, Aydın province has the highest number of producers with production diversity, while İzmir province has the highest honey yield, gross production value, and gross profit. This suggests that beekeeping farms in İzmir are leading in terms of economic sustainability.

Aydın and İzmir provinces rank first in terms of the social sustainability index, with Muğla province in second place. When considering the sub-indicators of social sustainability, Muğla has high labor input, but the prevalence of inter-regional migration in the province negatively impacts economic sustainability due to high transportation costs. This also has a negative impact on the welfare of bees and beekeepers, resulting in Muğla's ranking last in terms of social sustainability within the three provinces.

Based on the results, it would be advisable to limit beekeepers to migratory beekeeping within their respective regions in order to ensure the sustainability of beekeeping. This approach is considered an effective way to enhance the diverse ecotypes in various geographical regions and make them more accessible to beekeepers, while also preserving the genetic diversity of honeybees in Turkey, both currently and in the future.

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Crowdfarming. A public-private crowdfunding campaign to finance sustainable local food systems: A case study of short food supply chains in Madrid

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Abstract

Civic crowdfunding (CiC) and matchfunding (MF) are innovative private-public financing tools that can back projects with positive social and environmental characteristics. The purpose of this study is to analyse the potential opportunities and challenges of CiC with MF as a policy tool for local governments to finance place-based food initiatives and promote sustainable local food systems. The Matchfunding Madrid-Km-Región case study comprised three CiC calls in which institutional funds supplemented the money raised by crowdfunding campaigns for innovative short food supply chain projects. The results highlight the potential of CiC/MF to help local food project promoters to raise financial resources, as well as learn marketing skills and build a social support base around their projects. With the launch of CiC/MF campaigns, local and regional governments can enable innovative local food producers to launch their projects through community commitment. Further CiC/MF campaigns can support the entrepreneurship of agrifood initiatives in the region of Madrid. To do this, there is a need for more research and the dissemination of good practises.

Keywords*: Spain, Matchfunding, Civic crowdfunding, Short food supply chain, Finance, Local food system, Regional policies, Innovation.*

1. Introduction

The transition to more sustainable food systems involves strengthening local food systems (LFS), being short food supply chains (SFSCs) an essential part of these local food systems. Due to their proximity and close interaction with key local actors, local and regional governments are strategic actors in establishing resilient and economically prosperous LFSs (Galli *et al.*, 2020). In this sense, local and regional authorities are increasingly taking

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a leading role in supporting more sustainable food systems. This is highlighted by a variety of international agreements that put the emphasis on delivering actions for the sustainability of food systems at the subnational level (e.g., Milan Urban Food Policy Pact, New Urban Agenda-Habitat III [NUA], Glasgow Food and Climate Declaration).

There are various ways in which local administrations can promote SFSCs. However, one of the critical hurdles for local food initiatives is funding (Kneafsey *et al.*, 2013). This project analyses public-private partnerships as a way of financing SFSC-related projects. Specifically, it analyses a form of financing, civic crowdfunding (CiC) with matchfunding (MF), which involves local administrations and citizens who are interested in supporting local food initiatives.

Given the limited amount of research on community financing from the agrifood sector (Behrendt *et al.*, 2019), there is a call for more investigation and dissemination of CiC with the participation of subnational governments (Charbit and Desmoulins, 2017; Wenzlaff, 2020; Van Montfort *et al.*, 2021). In particular, more research is necessary in non-Anglo-American countries, especially taking into account the place-based nature of this mechanism (Wenzlaff, 2020). Furthermore, more research of crowdfunding dynamics in urban case studies (Langley *et al.*, 2020). This paper aims to contribute to filling the research gap on CiC as a tool for local governments by analysing its potential to foster local food initiatives. This research agenda can provide policymakers with more information on CiC and MF, providing for a greater number of such initiatives to be implemented and increasing their potential positive impacts**.**

The objective of this article is to analyse the potential opportunities and challenges of CiC with MF as a policy tool for local governments to finance place-based food initiatives and promote sustainable local food systems. The analysis is based on the results of the Matchfunding Madrid-KmRegión case study and their stakeholders' feedback. Matchfunding Madrid KmRegión is a CiC with MF campaign aimed at financing innovative projects related to short food supply chains (SFSCs).

2. Literature review

2.1. *Sustainable food systems and short food supply chains*

The complexity and length of the current globalized food system causes a concentration of power, social inequalities, and environmental issues (Princen, 2010; Blay-Palmer *et al.*, 2018; Corvo *et al.*, 2021). Sustainable food systems provide "food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised" (HLPE, 2014, p. 12). Sustainable local food systems are based on the idea that local food can be more economically, environmentally, and socially sustainable than conventionally produced food (Jarzębowski *et al.*, 2020; Marusak *et al.*, 2021). Sustainability depends on several factors, including food shelf life, spoilage rates, transportation distance, and costs associated with production processes along with transportation costs. Food system (re)localisation involves moving food systems back to local areas (Burgess *et al.*, 2022; Kapała, 2022). In this regard, an increasing number of consumers and producers are looking for alternative food systems such as SFSCs (Renting *et al.*, 2003; Kneafsey *et al.*, 2013; Kamble *et al.*, 2020). SFSCs can be seen as an alternative form of consumption, which allows consumers to reconnect with producers and with their production area (Marsden *et al.*, 2000; Corvo *et al.*, 2021). This reconnection can be seen as a way to strengthen relations between consumers and producers toward more equitable, social and fairer practices (Vittersø *et al.*, 2019). The European Union has also highlighted the importance of strengthening LFSs and SFSCs (European Commission, 2019), and its Farm to Fork Strategy calls on public policies to support them (European Commission, 2020).

SFSCs can be characterised through different approaches: physical distance, number of intermediaries, or its sociological implications (Grando *et al.*, 2017; González-Azcárate *et al.*, 2021a). In fact, European authorities defined SFSCs as "a supply chain involving a limited number of economic operators, committed to cooperation, local

economic development, and close geographical and social relations between producers, processors and consumers" (EU, 2013, p. 499). SFSCs meet the social demand to provide quality food while having the potential to reduce the environmental impact of agriculture (Jarzębowski *et al.*, 2020). Additionally, the development of SFSCs and preference for local food products was also found to be an effective strategy for preservation and development of urban agriculture, addressing the issue of food quality and security (Kamble *et al.*, 2020). Furthermore, alternative food networks such as SFSCs seem to bring producers and consumers with the aim of enhancing social equity and democracy to develop a more sustainable food system (Feenstra, 1997). The main niche for products arising from SFSCs are consumers with higher income, urban and educated ones (Kneafsey *et al.*, 2013). Some of the consumer interests on SFSCs are to access higher quality food (González-Azcárate *et al.*, 2021a), to fight climate change (Yu and Rehman Khan, 2022), to support more sustainable agriculture (Smith, 2008), or to provide better incomes for farmers (Marsden *et al.*, 2000; European Commission, 2019).

2.2. *Financing sustainable local food systems: Public-private crowdfunding*

Local and regional policymakers need useful policy instruments by which they can exert a significant impact on fostering sustainable local food systems (Kapała, 2022). There are many strategies that can be implemented in this regard, such as land use planning (Desjardins *et al.*, 2011), sustainable food procurement (Braun *et al.*, 2018; Lehtinen, 2012), farmers markets (Foti and Timpanaro, 2021), or local food awareness campaigns (Jia, 2021). These tools can support local food initiatives in several respects, but they do not eliminate the financial constraints facing them.

These funding barriers are caused to an extent by a financial sector that focuses its investments on an unsustainable food system, hampering the growth of local and alternative food systems, and forcing small and agroecological farmers to seek out loans on less favourable terms (Kneafsey *et al.*, 2013; Stephens *et al.*, 2019; Stephens, 2021; Yu and Rehman Khan, 2022). The current financial structure must be redesigned and equipped to support a radical transformation of food systems (CIDSE, 2020). This must go hand in hand with effective support from the public sector to foster an environment for small-scale investments in agriculture and supporting entrepreneurship in local food production, processing, and commercialization (Wezel *et al.*, 2018; CIDSE, 2020). In this regard, there is a need for changes in institutional tools to reduce the administrative and financial burden on the enterprises involved in LFS and SFSCs (Kneafsey *et al.*, 2013). This lack of funding also affects innovative small-scale food businesses (Stephens *et al.*, 2019).

To this end, socially responsible and impact investing-based financing mechanisms can be great allies in fostering sustainable local food systems (Behrendt *et al.*, 2019; Stephens *et al.*, 2019). In this sense, the consideration of broader social and environmental values is what sets up financing mechanisms based on the social and sharing economy as useful pathways for promoting sustainable food systems. The sharing economy is based on, usually digitally, interconnected networks of individuals and communities that transform the system of production, consumption, financing, and money lending (Méndez and Castaño, 2017). Also, the concept of the sharing economy is often linked to the social economy. The sharing economy and the social economy can have an important impact on building a more sustainable world (Ertz and Leblanc-Proulx, 2018; Stephens *et al.*, 2019). A potential example is civic crowdfunding (CiC) and matchfunding (MF) to help finance local food initiatives.

Crowdfunding has emerged as an important alternative to traditional financial mechanisms (Ljumović *et al.*, 2022; Kragt *et al.*, 2021). Crowdfunding came to the fore as a consequence of technological progress, combined with the funding shortages due to the 2008 financial crisis (Daskalakis and Yue, 2018). In this respect, the European Commission recognizes the potential of crowdfunding to finance social companies that have limited access to conventional sources of funding but are able to find the necessary funds for their projects through the wisdom of the crowd (European Commission, 2013). Consequently, crowdfunding can be seen as a tool to

democratise finance in Europe (ECN [European Crowdfunding Network], 2018).

Ojo (2021) highlighted some benefits that crowdfunding offers entrepreneurs: (1) financing new ideas or existing business, (2) marketing purposes, (3) awareness among potential customers, the general public, and the media, (4) market test that signals whether potential customers are interested in the respective offering of a crowdfunding campaign, and (5) signaling public approval of a cause. However, there are no studies that investigate the characteristics and motivations of crowdfunding entrepreneurs in an agribusiness context (Kragt *et al.*, 2021). On the donor side, the behavior of contributors is based on a combination of intrinsic and extrinsic motivations (Bagheri *et al.*, 2019). The key to the concept of local crowdfunding in the agricultural sector is whether people ascribe a higher value to local causes, those that are visible in their neighborhood (Stoknes *et al.*, 2021)

CiC defines a subcategory of crowdfunding whose aim is to collect funds for projects in the public domain or with a common social objective (Davies, 2014). This modality is normally based on public-private partnerships that mobilize the community to offer infrastructure and services, facilitating coproduction, information exchange and citizen commitment (Davies, 2014; Charbit and Desmoulins, 2017). CiC does not necessarily have to produce a public good; it can offer spillover benefits derived from private goods (Davies, 2014). In this respect, CiC can encourage business investment in certain areas and can be very useful for governments to address challenges such as social or environmental sustainability (Charbit and Desmoulins, 2017). In fact, successful crowdfunding campaigns are more likely to have highlighted their larger social or environmental purpose of the enterprise or project in question (Langley *et al.*, 2020). Regarding public spending, CiC can be a great opportunity to carry out projects in a context of limited resources, allowing the implementation of projects that would not otherwise be feasible without private donations (Davies, 2014; ECN, 2018; Gasparro, 2018; Brent and Lorah, 2019; Langley *et al.*, 2020). In this sense, CiC has certain characteristics that stress its role as a complement rather than a substitute for public spending. First, CiC is not suitable for projects that depend on sustainable financial support over a long period (Charbit and Desmoulins, 2017; Hong and Ryu, 2019). Furthermore, CiC is normally intended for small-scale projects and cannot be conceived as a direct replacement for all government spending on infrastructure (Brent and Lorah, 2019; Langley *et al.*, 2020). In other words, CiC is a mechanism to foster one-off projects that have broad social support, but do not receive funding through conventional channels. It is the interaction with the local community that makes CiC a tool with enormous potential for local and regional government initiatives (Charbit and Desmoulins, 2017).

MF is a crowdfunding mode in which citizen contributions are supplemented by a substantial contribution from a private or public institution that seeks to foster a specific line of action. The additional contribution from the public or private institution encourages private microdonations, which raises the total amount collected compared to a traditional crowdfunding campaign (Senabre and Morell, 2018; Brent and Lorah, 2019). MF tends to be used more frequently in CiC campaigns than in other types of crowdfunding campaigns. This is because CiC pursues objectives of general interest that justify the contribution of funds by public institutions, while companies can also contribute as part of their corporate social responsibility. Therefore, CiC campaigns are not only a tool for financing local projects that contribute to sustainable development but can also set a political and social local agenda around the SDGs (González-Azcárate *et al.*, 2021b). Through CiC and MF, local or regional governments can promote a particular line of action that benefits the community, such as culture or sustainable mobility. Note also that crowd participation is not limited to funding, but the projects can be also crowd-designed/crowd-sourced. In this regard, CiC can also be a guide for public investment, as a CiC campaign can be used by governments to gauge the acceptance that certain initiatives are likely to have among citizens and schedule larger investments in the future (Langley *et al.*, 2020). In this sense, it has to be considered that CiC promoted by governments could be unequally since only those with the social capital

necessary to encourage private cash, capital, and collective enthusiasm necessary for the crowdfunding campaign can drive priorities of public spending (Langley *et al.*, 2020). For this purpose, it is necessary to analyse the source of contributions and how participatory the crowdfunding campaign was (Davies, 2014; ECN, 2018; Brent and Lorah, 2019). Although a lot of diverse information about the dynamics of CiC and MF is already available, more practical studies of CiC carried out by local governments in different areas are needed to understand CiC in practise (Van Montfort *et al.*, 2021).

2.3. *Short food supply chains and matchfunding: Promoting social capital for sustainable food systems*

Social capital has become an important analytical concept and a policy tool, in local development (Rivera *et al.*, 2019) and agricultural innovation (Cofré-Bravo *et al.*, 2019). The notion of social capital reflects the links between people who know each other and the trust between them (Rivera *et al.*, 2019). Social capital refers to resources embedded in networks that can be mobilized through social interactions, and that can lead to potential benefits for both individual and collective actors (Lang and Fink, 2018). Ding *et al.* (2020) distinguish between two distinct features of social capital. The first category of social capital focuses on community involvement, providing information on the community's ability to cooperate and provide public goods. The second category of social capital focuses on individual commitment to social institutions, when people demonstrate that they are willing and able to incur a cost to contribute to societal objectives. This provides information on the community's ability to mobilise its individuals to address collective problems.

Social capital has been identified as a critical entry point for community change (Lamm *et al.*, 2022). In the context of LFS and SFSC, the nature of the connections among stakeholders is an important feature, and there is a potential to generate social capital by facilitating connections between producers and consumers. At the same time, social capital can contribute to the development and strengthening of SFSCs and LFSs, although it is difficult to quantify (Thilmany *et al.*, 2021). In this line, Béné (2020) suggested that strengthening social capital contributes to a more resilient LFS.

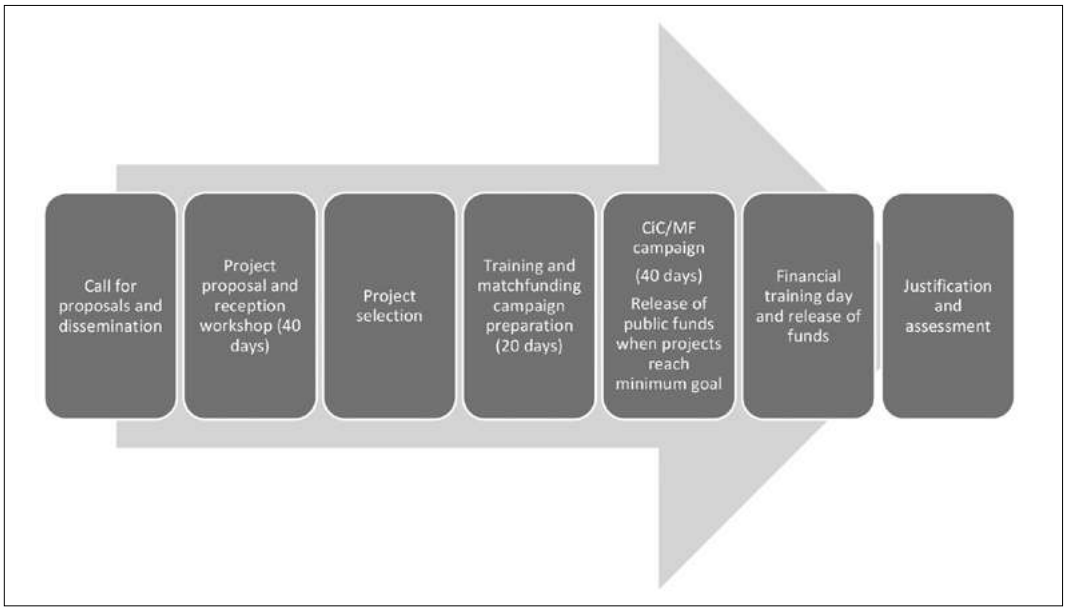
According to previous sections, SFSC and MF are supported by the connections of farmers-consumers and farmers-donors. In both cases, social capital is generated, and it can be used in the development of sustainable local food systems, being local public polices a relevant success factor. In this sense, little research explores how rural social entrepreneurs deal with the complex interplay of different forms of social capital when developing their business model (Lang and Fink, 2018). Additionally, little has been reported on the utility of rural social capital (Li *et al.*, 2022).

3. Materials and methods

3.1. *Description of the case study*

The Madrid region is an urbanised and densely populated region in central Spain, where the primary sector has only a small share in the regional economy. However, proximity to such a huge market has fostered the development of SFSC initiatives (Yacamán Ochoa *et al.*, 2019). Regarding the current state of SFSCs in the Madrid region, public policies can reduce the difference between current SFSC consumers and consumers willing to buy from SFSCs (Cruz-Maceín and Dorrego-Carlón, 2019; González-Azcárate *et al.*, 2021a). The Matchfunding Madrid-KmRegión was defined as a CiC call with institutional support for innovative local and sustainable SFSC projects in the Madrid region. It was led by the Madrid-KmRegión operational group (for more information about operational groups, see EU, 2013) within the framework of the Rural Development Programme for the Autonomous Community of Madrid. Three Matchfunding Madrid-KmRegión project calls (2018-2021) were launched. These calls were aimed at new or existing SFSC projects in the Madrid region, whose promoters wanted to make innovative investments and acquire new loyalty links with consumers. For this purpose, institutional funds supplemented the money raised with citizen support in crowdfunding campaigns carried out by the selected

Figure 1 - Matchfunding Madrid-KmRegión stages.



projects, making this a MF and CiC campaign (hereafter CiC/MF). As defined by Davies (2014), the operational group played a facilitator role, in which authorities launched calls for specific proposals on a given issue, trained project promoters, and topped up the financial resources provided by the crowd. After the launch call, 43 projects were submitted and evaluated by a panel made up of university scientists in SFSC, consumer and producer associations representatives, MF specialists and experts from the Spanish agroecology association. They evaluated the projects considering: (1) agroecological criteria such as sustainable and zero waste production criteria, technical-commercial criteria of the projects, or packaging and wrapping procedures. (2) Economic-financial criteria such as clarity and detail of the budget presented, viability of the investment, coherence of the economic information with the objectives of the project presented. (3) Community and communication criteria such as commercial networks already created, project's dissemination capacity, presence in social networks, and the scope of the promoter's community.

The crowdfunding campaign had to achieve a minimum collection goal and a minimum number of donors to unlock the matching funds that doubled the minimum target amount, thus ensuring the viability and public interest of the co-financed projects (Minimum target for €2,000: 30 contributions, Minimum target for €3,000: 50 contributions; minimum target for €5,000: 70 contributions). Citizens had the option of donating an amount of money of their choice or of contributing an amount associated with a reward. In Figure 1, the whole process of the Matchfunding Madrid-KmRegión is displayed.

3.2. *Methods*

To achieve the objective of this study, analyses were performed on a combination of qualitative and qualitative data sources. In addition, the authors of the present paper attended all meetings during each phase of the three Matchfunding Madrid-Km Región calls during 2019, 2020 and 2021: Madrid-KmRegión operational group meetings, public announcements of the CiC/MF calls, workshops with the promoters, and events during the crowdfunding campaigns.

First, quantitative data was collected from the crowdfunding platform, from which anonymized information about the monetary contributions was extracted (amount, project, date, location, donation-based or reward-based). Second, an online survey was sent through email to every crowd-

funding contributor after each campaign ended. A total of 212 respondents completed the survey. Sixty-four people took the survey after the first CiC/MF campaign in 2019, fifty-one people completed it after the second call in 2020, and ninety-seven contributors filled in the survey after the last campaign in 2021. The survey was presented by a summary of the research purpose and contained questions about the nature of the contribution (project, date, and amount, reward-associated or donation), motivations to contribute to the campaigns, previous knowledge of crowdfunding, campaign communication, the public sector matching fund incentive, food-buying related habits, and sociodemographic data (age, occupation, family unit size, post code, incomes). The full content of the survey is available in Appendix I. Both data sets were descriptively analysed using SPSS version 24.

In addition to quantitative data, semi-structured interviews with every project promoter (n = 13) were held in each call approximately one month after their crowdfunding campaigns were over. The interviews were divided into three parts, one about the situation of the venture before applying for the CiC/MF call, another about the crowdfunding campaigns, and the last one about the output of the CiC/MF. The interview guide is available in Appendix II. These interviews were recorded and transcribed. A textual analysis was then performed to pinpoint common perspectives among promoters. Lastly, a discussion group was held with the stakeholders involved in the development and implementation of the project (operative group partners, crowdfunding platform technicians, and researchers) to discuss and evaluate the results of the three Matchfunding Madrid-KmRegión campaigns, providing feedback for this research. A thematic analysis was performed to validate the conclusions of the present research.

4. Results

4.1. *Project characteristics and results of crowdfunding platform*

Of the 43 projects submitted to the three CiC/MF calls, 13 were selected. All crowdfunding campaigns were successful and reached the established minimum collection goal and the minimum number of donors, thus releasing the matching funds.

Table 1 shows the main data on the objectives and results of each campaign. Most of the projects reached their minimum goal toward the end of the campaign. The only two projects that reached the minimum within the first 13 days were based in the city of Madrid. The other projects were based in rural or peri-urban areas of Madrid.

In total, 1331 private contributions were made. About two out of every three contributions had an associated reward, while the other third were free donations. Additionally, six people offered their services to collaborate on the project (web setup, filmmaking, etc.). Lastly, it should be underlined that 10% of the donors contributed around one third of the total amount collected. The crowdfunding campaigns lasted between 42 and 44 days and were much more active at the beginning and especially at the end, with a slowdown during the middle period.

4.2. *Donor feedback*

This section reports the results extracted from the survey sent to donors. Table 2 shows the sociodemographic profile of the survey respondents. The median distance between the donor's home and the project was 12 kilometres (Min: 0,5 km, Max: 501km), which highlights the localism of this financing mechanism (mean distance can be highly distorted by occasional donations from other parts of Spain). Most of the donors surveyed live in the city of Madrid. The shortest distance to donors was for projects based in the urban area of the Madrid region and for the two CSA (community-supported agriculture) projects. On the other hand, other projects that are based in rural areas received donations from more distant locations, mainly from the urban areas of Madrid, where most respondents lived.

Motivations based on the project and the community were more highly rated than individual benefits, where the project topic was the most highly rated (Table 3).

The sample is made up of consumers with wide-ranging relationships with promoters. One third of the donors had a previous business relationship with the project, another third had a prior

Table 1 - Matchfunding Madrid-KmRegión selected projects and crowdfunding results.

Call	*Project*	*Location*	*Definition*	*Status*	*Objective*	*Number of donors*	*Min. goal*	*Day when minimum objective is reached*	*Optimum goal*	*Raised amount*	*Matched funds*	*Most demanded reward*
2019	1	Rural	A cooperative logistical center for small agroecological food producers	Creation	Cover communication costs, wages for coordinator and salesperson.	92	€3,000	33	€9,500	€7,642	€3,000	Public acknowledgement (€15)
2019	2	Peri-urban	An alliance between two projects to deliver agroecological products to Madrid by bicycle	Creation	Adapt delivery management software, buy an electric bicycle, acquire a second-hand van, cover publicity and communication costs.	135	€3,000	38	€15,000	€7,950	€3,000	5 kg agroecological food basket (€60)
2019	3	Urban	A cooperative consumers' supermarket	Expansion	Rent bigger premises, buy an industrial fridge, update computer and software, acquire shelves and furniture.	85	€3,000	13	€10,000	€14,120	€3,000	One-year membership + agroecological food + acknowledgement + merchandising (€100)
2020	4	Rural	The creation of a cooperative composed of five agroecological farms	Creation	Cover rewards costs, coordination issues, commercial issues, logistic coordination, marketing campaign.	140	€4,500	19	€12,000	€10,945	€4,500	5 kg agroecological food basket (€30)
2020	5	Rural	A farm based on community-supported agriculture	Expansion	Increase wages by 10%, increase working hours of administrative assistant, buy a container.	137	€4,500	24	€14,000	€14,040	€4,500	One-year membership (€40)
2021	6	Urban	A cooperative consumers' supermarket	Expansion	Buy displays, advertising materials, communication, educational actions, web improvement.	244	€2,000	2	€10,000	€13,533	€2,000	A mixed basket (soap, magnet, stickers, fabric bag, etc.) + food basket raffle participation (€30)
2021	7	Rural	A farm based on community-supported agriculture	Expansion	Hire a second farmer.	121	€3,000	30	€12,000	€13,305	€3,000	Donation of choice

Call	*Project*	*Location*	*Definition*	*Status*	*Objective*	*Number of donors*	*Min. goal*	*Day when minimum objective is reached*	*Optimum goal*	*Raised amount*	*Matched funds*	*Most demanded reward*
2021	8	Rural	Agroecological farm that produces local traditional varieties	Creation	Buy a stone mill, rent a storehouse, rent more land, raise workers' wages.	58	€2,000	38	€6,000	€4,285	€2,000	One-year membership to participate in the activities + 7 kg of potatoes, flour and chickpeas (€30)
2021	9	Rural	A small company that grows different species of edible and medicinal mushrooms in Madrid	Creation	Air condition facilities, buy raw materials, acquire automatic watering and humidification equipment.	38	€2,000	37	€7,000	€4,305	€2,000	3 kg of assorted mushrooms (€30)
2021	10	Rural	Agroecological farm that produces local traditional varieties	Expansion	Create promotional materials, renew pergola, buy fridge, acquire furniture for the visitor zone.	92	€3,000	33	€10,100	€6,943	€3,000	10 kg of agroecological fruits and vegetables and vouchers to buy in the store (€30)
2021	11	Peri-urban	Shepherds that herd their flocks to clear green spaces around Madrid	Expansion	Build a mobile dairy to produce cheese while the sheep are clearing green spaces around Madrid.	60	€3,000	38	€8,000	€6,050	€3,000	Cheese tasting (€30)
2021	12	Rural	Shepherds located in the northern part of Madrid	Expansion	Create a CSA, acquire machines for food processing.	55	€2,000	25	€5,000	€5,197	€2,000	Donation of choice
2021	13	Rural	Association of agroecological producers	Expansion	Create sales web, improve the farm, buy second-hand van, renew greenhouse.	74	€3,000	33	€10,500	€6,665	€3,000	5 kg of agroecological fruits and vegetables and a fabric bag (€40)
					TOTAL	*1331*	*€38,000*		*€129,100*	*€114,980*	*€38,000*	

Table 2 - Sociodemographic data of the survey respondents.

Age group	18 - 35	12.4%
	36 – 55	53.6%
	56+	34.0%
	Average age (years)	50.0
Education	Uneducated	0.0%
	Primary education	1.9%
	Secondary education	11.8%
	Higher education	86.3%
Monthly net income per household	Up to €1,000	4.5 %
	From €1,000 to €2,000	22.5 %
	From € 2,000 to €3,000	32.5 %
	From €3,000 to €4,500	29.0 %
	More than €4,500	11.5 %
Number of people per household (mean)	2.5	
Monthly net income per household (mean)	€ 2,50	
Monthly net income per person (mean)	€1332.6	

Table 3 - Survey results regarding motivations for contributing, food purchasing habits and donated amount.

	Mean	*SD*
How much money did you donate? (€)	69.7	62.1
MOTIVATIONS FOR CONTRIBUTING (where 1 is unimportant and 5 is very important)		
Project topic (agroecological food SFCSs in the Madrid region)	4.7	0.7
Support for a project that will benefit the local community	4.6	0.8
Project information	4.3	0.9
Support for the people behind the project	4.0	1.2
Support for a project from which I will benefit as a customer	3.0	1.3
Amount of money raised before my contribution	2.2	1.2
Direct reward in return for my donation	2.1	1.2
Recognition as a donor	1.7	1.1
HOW OFTEN DO YOU BUY… (where 0 is never and 10 is always)		
…organic food	6.9	2.6
…local products	5.9	2.6
… directly from producers	5.5	3.2
…products with a Protected Designation of Origin label (PDO)	5.4	2.5

Table 4 - Survey results regarding donors' relationship with the promotors and perceptions of other aspects of the campaigns.

Did you know the promoter/s before?	
Business relationship (customer)	39.2%
Personal relationship	37.7%
I had heard about him / her / them, but I had never had contact	8.0%
I didn't know him / her / them	15.1%
How did you find out about the crowdfunding for the project? (Mark only the main source)	
From promoter social networks	35.4%
In person from the promoter/s	34.9%
From family and friends	17.4%
From the TRIODOS Foundation	11.3%
Others	1.0%
Did you promote the campaign?	
Yes, on social networks	26.9%
Yes, by word of mouth	25.5%
Yes, on social networks and by word of mouth	23.1%
No	24.5%
Would you participate in another civic crowdfunding campaign within a year?	
Yes	58.5%
Only MF (where local or regional governments supplement the funds raised by crowdfunding)	8.0%
Only for similar projects (projects by local food producers from the Madrid region)	8.0%
No	.5%
I don't know	25.0%
Now that the crowdfunding campaign has ended, what information do you want to receive about the progress of the project to which you donated?	
Regular information about project progress	48.1%
A final report once the project has been fully implemented	39.6%
I am not interested in receiving more information	4.7%
I don't know	7.5%
Did you know before that the public administration participated by selecting the projects and doubling the funds?	
No	69.3%
Yes	30.7%

personal relationship with the promoter/s, and the last third had no prior knowledge of the project (Table 4).

In fact, most of the respondents learnt about the CiC/MF call through promoter networks, and three-in-four helped to disseminate the CiC/MF. After this experience, a large percentage (74%) of the respondents would be willing to participate in a crowdfunding campaign again, regardless of the crowdfunding topic, and most (88%) are interested in receiving updates on the project progress (Table 4).

Interestingly, most (69%) of the sample did not know that the money raised was topped up by public funds (Table 4). This is mainly due to the fact that the 2019 crowdfunding campaign did not highlight this point, while the 2020 and 2021 campaigns placed a bigger emphasis on

Table 5 - Survey results regarding donors' perceptions about the involvement of the public administration.

If the public administration had not contributed extra funds, how much would you have donated?	
I would have contributed the same amount of money	80.0%
I would have contributed less money	6.3%
I would have contributed more money	4.2%
I would not have contributed	0.0%
I don't know	9.5%
Rate how the participation of the public administration has contributed to the following aspects of the project (where 1 is unimportant and 5 is very important)	
Confidence in the proposed budget	1 = 16.5%
	2 = 9.4%
	3 = 29.4%
	4 = 22.4%
	5 = 22.4%
	Mean: 3.2
	SD: 1.3
Confidence in how the money would be spent	1 = 15.6%
	2 = 11.1%
	3 = 18.9%
	4 = 21.1%
	5 = 33.3%
	Mean: 3.5
	SD: 1.4

this issue. In fact, most (80%) contributors would have donated the same amount with or without match funds, although it did have a positive impact on donors' confidence in the feasibility and accountability of the selected projects (Table 5).

Finally, it has to be considered that the survey sample might be somewhat biased as, possibly, contributors that have a closer relationship to the promoters are likely to feel more duty bound to fill out the form.

4.3. *Promoter perceptions*

The feedback from the promoters had some points in common with the issues raised by the survey respondents. Firstly, 77% of them heard about the CiC/MF call through regional agroecological and local food networks. Secondly, all promoters already had an interest in raising financial resources for investment in their projects, although the CiC/MF call was the trigger that finally set the ball rolling. The campaigns required considerable effort but paid off in view of the results.

> *We had to work long working hours. Rather than investing in resources, it takes a long slog. However, I think the work effort is proportional to what a crowdfunding campaign entails and it is definitely worthwhile in view of the results.* (Rural project)

In this vein, all promoters were satisfied with the results and would again participate in a CiC/MF campaign. According to them, direct communication channels (email, instant messaging, and word of mouth) were the most efficient channels for encouraging donations from friends, family, partners, and regular customers, who normally donated at the beginning of the campaign. On the other hand, social media campaigns were more effective at engaging with new supporters who normally donated

towards the end of the campaign. In general, most campaigns stressed project proximity and environmentalism, as well as particular project features (e.g., involves young farmers, led by women, etc.).

Thanks to the matchfunding, we have been able to move away from the precarity in which we were operating. We were able to change the business model for next year and hire more staff. Also, thanks to the preparation of the campaign, we learnt to better specify our marketing plan and managed to expand our structure by reaching out to new interested customers. (Rural project)

The CiC/MF has meant a leap in project scale not only in economic terms but also through the generation of bonds of trust with customers/consumers and the community. This was a huge boost in morale, as promoters realized that there is a social base that supports the project. In this sense, most promoters acknowledged other returns of CiC/MF, such as an expansion of their customer and supporter base, the acquisition of knowledge about marketing tools, and an increase in their business online visibility of their business. Many promoters also remarked that MF paperwork was easier to fill out and assured a greater social interest than a subsidy process. All projects were intended to continue to engage donors by providing updates on the progress of the project. Furthermore, they highlighted that since their projects had been selected and supported by a public authority, they had greater credibility and visibility, as if they had been awarded a "quality seal". Regarding points for possible improvement, many producers commented on the possibility of dividing the minimum goals for releasing the funds into more progressive bands, more flexible deadlines, and more counseling after the end of the campaigns (rewards management, how to establish further links with donors, etc.).

In a subsidy process, you normally have to advance the money and receive a refund a long time afterwards after justifying all payments. Matchfunding bureaucracy is much simpler. Besides, I prefer crowdfunding because I engage with my community, which analyses and controls the investment. I think financial relationships are healthier. (Urban project)

Lastly, the discussion group offered positive information on Matchfunding Madrid-Km-Región results. One of the main common points of this discussion was that the people/institutions involved in the project will look for ways to foster more CiC/MF campaigns related to local food initiatives in the region. Municipalities appeared to be the most suitable partners to develop future initiatives. In this vein, participants also noted that the major barriers to fostering this mechanism in local governments were the lack of knowledge, as well as legal and administrative methods to carry out CiC/MF campaigns.

Based on trends in participatory budgets and so on, I believe matchfunding would be well received by municipalities. However, they are unfamiliar with this system, and, those who are, do not know where to start and how to fit this mechanism into their subsidy processes. (Researcher)

5. Discussion

5.1. *Crowdfarming as a tool to support sustainable local food systems*

The results section implies that CiC/MF entails interesting options for promoters, donors, and local and regional governments. In the Matchfunding Madrid-KmRegión initiative, promoters not only collected resources for their projects, but also obtained different benefits that go beyond the simply act of receiving funding, such as visibility increase or customer base expansion. In line with the literature, it can be considered as a tool that tackles several project fronts, such as visibility (Baeck *et al.*, 2017; Ojo, 2021; Stoknes *et al.*, 2021), marketing (Stephens *et al.*, 2019), consumer interactions (Bitterl and Schreier, 2018), and market test to explore specific product or service acceptance among potential consumers. The success of the Matchfunding Madrid-KmRegión reinforces the potential of this tool to promote SFSC, as it tackles finan-

cial constraints of these chains (Kneafsey *et al.*, 2013; Wezel *et al.*, 2018; Stephens *et al.*, 2019; CIDSE, 2020), while also providing promoters with more tools for their projects.

It was observed how CiC/MF about SFSCs strengthens the commitment of existing consumers to projects. Donors directly funded the initiative, going beyond the simply purchase of food, and having main motivation to support a project within a model of agriculture that they are demanding, therefore generating social capital. In addition to the links generated by a closer relationship between consumers/producers based on SFSC, there are also the links (promoters/donors) derived from CiC/MF. This engagement of donors, as well as their willingness to support similar projects in the future, demonstrates how CiC/Mf can be a great tool to generate social capital in the context of SFSCs (Ding *et al.*, 2020), thus promoting more sustainable food systems (Béné, 2020). The CiC/MF campaign appears to be an outstanding approach to mobilizing the community around a project or line of action. The present paper highlights two main donor profiles: the local community (family, friends, and neighbours) and consumers from urban areas demanding SFSC products. These links (local producers/consumers and rural/urban areas) through SFSC contribute to the development of a stronger sustainable local food system and to the promotion of rural development. This is consistent with the findings of Behrendt *et al.* (2019), who stated that community financing models can encourage committed consumers to develop a more sustainable food system. It has to be noted that the sociodemographic profile of the donors was people with higher income, urban and educated ones, in line with the main market niche of SFSCs (Kneafsey *et al.*, 2013).

In terms of social capital, these links could translate into community engagement and individual commitment to social institutions (Ding *et al.*, 2020). In our case study, the community engagement could be mainly associated with the links between local producers and local consumers. On the other hand, individual commitment could be mainly associated with the support received between rural and urban areas. In terms of SFSC, both types of social capital contribute to reduce the physical distance and number of intermediates between producers and consumers.

Developing social capital requires a good communication strategy. CiC/MF has to be widely disseminated and clearly specify its objectives. Local and direct communication plays an important role, especially to reach the closest contacts (family, friends, neighbours). As the results showed, these are the first support for CiC/MF and SFSC initiatives. However, there are donors who do not fall into these direct relationships (at least 23% of donations came from outsiders). Social media and communications through regional networks made possible to spread this project beyond direct contacts to build new rural and urban links. In these cases, the motivations for the donation focus on attractiveness of the project and the affinity with its objectives. In the present case study, the environmental dimension and interest in more sustainable food systems was what mainly drove this type of donations.

5.2. *Fostering "crowdfarming" from local and regional policies*

The involvement of local and regional governments presents additional advantages. Firstly, these calls reinforce the advantages for consumers, producers, promoters, and donors. For promoters, the most important contribution from local and regional governments involvement seems to be in terms of generating credibility and gaining visibility. For donors, the fact that public funds were provided to supplement private donations was not a major driver, especially in the first campaign. However, donors who knew about the complementary funds positively rated their impact on confidence in and accountability for the selected projects. In the Matchfunding Madrid-KmRegión initiative, the "match" with public funds tended to encourage producers rather than consumers to participate in the CiC/MF. However, this may not be the general case and further research on the role playing by governments to involve more consumers should be carried out in other study cases. There are also advantages for local and regional governments insofar as they contribute to closer links between production and consumption, between rural and

urban areas. The social capital derived from these links is also key for other regional and local food policies (Thilmany *et al.*, 2021).

In addition, more institutional tools to reduce the administrative and financial burden weighing on SFSC enterprises (Kneafsey *et al.*, 2013). The success of this case study suggests that CiC/MF is potentially a very suitable alternative for this purpose. One advantage that CiC/MF has over traditional public sector subsidies is that it assures that a project has interested people willing to support/participate in the project once it has been implemented. Traditional public subsidies are hard to provide any such guarantee. Another advantage of MF over direct payments highlighted by promoters is less bureaucracy and fewer administrative procedures, as it was raised by promoters. Public grants are intended for the same purposes as CiC campaigns but require open tenders and complex administrative processes to ensure transparency and the correct management of public grants. On the other hand, CiC/MF provides for fundraising in a shorter time and with a lower administrative workload, while simultaneously guaranteeing transparency throughout the entire process (Baeck *et al*., 2017; ECN, 2018). In the Matchfunding Madrid-KmRegión initiative, the requirement to achieve a minimum collection goal and a minimum number of donors was the main mechanism used to avoid cronyism in the release of public funds. This mechanism can be effective in redefining current public subsidy systems, tackling the financial problems of the small-scale agroecological sector, and supporting entrepreneurship about local food initiatives. These transparency and accountability features offered by CiC/MF are also a requirement for a well-functioning participatory and democratic food system (Feenstra, 1997; Stephens *et al.*, 2019). This makes CiC/MF a mechanism that is very well matched with the creation of democratic food systems, where consumers are involved in defining the model of the food system they want.

According to the advantages referred to CiC/MF in the literature (Senabre and Morell, 2018; Brent and Lorah, 2019), this study has shown how public policies (for example, facilitating management, complementary funds) are strengthened by citizen support. The results presented also show how these CiC/MF calls can contribute to the long-term viability of the supported action by the administration, insofar as 87% of donors wanted to remain informed about the projects they have funded. In this sense, the support that CiC/MF campaigns bring to future local food policies is an additional advantage that can be inferred from the results of both consumer surveys and producer interviews.

The joint analysis of the Matchfunding Madrid-KmRegión case study offers insights into the potential of CiC/MF as a tool to foster local food initiatives. This crowdfunding mechanism is suitable for financing small local agricultural initiatives, which is another way of shortening the food chain by putting consumers in contact with producers not only with a view to food purchase/sale but also to raising the funds that many of these projects need to start up or expand. This case study has substantiated how this instrument enables innovative local producers that have difficulty gaining access to traditional financing (ie, small-scale family or young farmers) to materialise their projects through a community commitment to local agriculture.

Note that although CiC/MF is a potentially great mechanism to support sustainable local food systems on the local and regional scale, only around 2% of the total number of CiC campaigns belonged to the food field in Spain (Díaz and Cacheda, 2016). Therefore, this is an area with a huge potential for growth considering that European institutions are developing policies aimed at supporting local food products and the circular economy.

5.3. *Limitations of "crowdfarming"*

Many proposals were submitted, but only a few projects were approved by the selection board. The first step in a successful MF call depends on an expert previous selection of projects. This selection avoids promoters to implement an exhausting but fruitless crowdfunding campaign. The selection process requires a considerable number of experts in different disciplines to carry out a good selection procedure, which can be a limitation in some contexts.

Furthermore, running a successful crowdfunding campaign takes a lot of time and effort, as the promoters. Additionally, promoters need a relevant previous network to ensure the success of the crowdfunding campaign. Additionally, the communication campaign should be oriented to a general public but also it must elaborate strategies to reach specific targets, which requires a good strategy. All this necessity reflect that this mechanism is not an option for every kind of producer or promoter, narrow down the number of projects that could be supported through CiC/MF.

On the contributors' side, the general profile reveals that CiC/MF for local food projects needs a critical awareness population on the topic. The calls should be focused on topics that have a minimum of concerned population, which is a limitation for many contexts without an enough number of concerned consumers. In the case of SFSCs, CiC/MF seems to be a useful tool in these territories where these initiatives are relevant to a certain number of consumers, as is the case of the Madrid population. In addition, CiC/MF campaigns about SFSCs seems to embrace a very particular social profile (i.e., high education and incomes), also limiting his impact in broader segments of the population.

Other barriers to CiC/MF identified in previous research are the lack of technical and administrative knowledge about CiC/MF, a possible shortage of projects submitted by private initiative, or the failure to encourage citizens to contribute (González-Azcárate *et al.*, 2021b). Furthermore, this research highlighted that CiC/MF was a totally unknown to local policymakers within the Madrid region, although there was a great deal of interest in implementing CiC/MF campaigns related to local food chains in their municipalities (González-Azcárate *et al.*, 2021b). However, CiC/MF calls need for partnerships with specific platforms and specialised professionals to run them, which may be a limitation for small councils.

5.4. *Research limitations and perspectives*

Those who responded to the questionnaires appear to be mostly those who personally connected with the promoters, which can bias the results on the perception of the donors. In addition, since the research is based on a single case study, there is a need for more research on CiC/MF campaigns to foster LFSs on different contexts to be able to confirm the external validity of the present results. In this sense, further research should address other benefits of CiC in addition to funding, such as building networks or creating synergies around a line of action (Stiver *et al.*, 2015). According to Charbit and Desmoulins (2017), more research is also needed on barriers and good practices in the field of CiC with the participation of regional and local governments. Senabre and Morell (2018) also remarked on the need to compare CiC/MF with other collaborative financing mechanisms, such as municipal participatory budgeting, digital social currencies, and time banking. Lastly, although crowdfunding for the agrifood sector is growing globally, there is still a need for more research in this area (Troise *et al.*, 2021). This could provide a better understanding of viable alternatives for social initiatives that would otherwise not have access to resources. On another note, the campaigns faced more hurdles in rural areas due to less consumer awareness of the projects. This should be further studied in search of possible adaptations that increase the impact of CiC/MF in rural areas.

6. Conclusion

This case study has highlighted a number of benefits of CiC/MF as a tool to support sustainable local food systems. This tool offers interesting options for promoters, donors, and local and regional governments. The combined analysis of these results shows important synergies that reinforce the benefits of public-private partnerships for the financing of local and regional food projects. However, it is a tool applicable only in specific contexts, and some limitations are discussed in this paper.

The CiC/MF represents both an opportunity and a challenge for local and regional governments that want to support rural development by creating and expanding agrifood initiatives that contribute to the establishment of a more sustainable food system. As the knowledge of CiC/

MF among governments appears to be limited, there is a need for a greater dissemination of good practises, more research, and support to enable local and regional authorities to launch CiC/MF calls.

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Exploring consumers' beef preferences using a stated method approach: Disentangling differences throughout the value chain

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JEL codes: C25, C42, Q11

Abstract

It is increasingly important that the extensive livestock systems become more resilient and market orientated to face current challenges. But this can only be achieved by more interconnected supply chains where consumers' expectations are understood and the benefits of the production systems are communicated to the final consumer. This paper focuses on an array of meat attributes and their role in consumers' preferences, from both consumers' own perspective and the opinions of other value chain agents. The former was studied with a consumers' survey and a choice experiment, while the latter was investigated by the Delphi method. The study was carried out in a major beef consuming region in Spain, characterised by the presence of extensive cattle farming systems. Results reveal the existence of a niche market for more differentiated beef, where health qualities and local origin are particularly appealing. The ranking of preferences elicited through the rating-scale and the choice experiment are mostly consistent. We also find a certain degree of divergence between the agents' valuations, being wider with those placed farther from the consumer, as is the cattle farmer.

Keywords*: Beef chain, Credence attributes, Labelling, Delphi, Rating, Choice experiment, Consumer.*

1. Introduction

The Farm to Fork strategy initiated by the EU, aims at achieving healthier, fairer and more environmentally friendly food systems (European Commission, 2021), highlighting the need for further collaboration and communication at every step of the food chain, the adaptation to consumer demand, and the reinforcement of the farmer's position in the value chain. In this context, extensive livestock farming, especially that based on agroecological systems, may play a relevant role. The extensive livestock farming not only provides public goods related to the ecosystem services (e.g. preservation of autochthonous endangered breeds or the provision of habitats for biodiversity) (Rodríguez-Ortega *et al.*, 2018), but it can also bestow upon meat with a more adequate fatty acid profile and other health benefits (Domaradzkia *et al.*, 2017) and may enhance sensory characteristics, such as tenderness (Serrano *et al.*, 2017). Consequently,

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if well communicated through the supply chain, these characteristics would help to mitigate current consumers' concerns on beef production, including ethical, environmental and health concerns (Aboah and Lees, 2020; Sans and Combris, 2015; Verbeke *et al.*, 2010). Furthermore, the use of autochthonous breeds in extensive livestock systems, reinforce the benefits of the system, preserving biodiversity while simultaneously contributing to the cultural and gastronomic heritage (Coutinho *et al.*, 2021).

The Northwest region of Spain (Cantabria), where this study was carried out, is one of the major consuming regions of beef meat in Spain. In 2019, the average per capita consumption at home was 7.41kg compared with the average for Spain of 4.85kg (MAPA, 2020). Cantabria is characterised by the presence of extensive cattle farming systems using two autochthonous endangered breeds (Monchina and Tudanca) mainly located in rural mountain and Less-Favoured Areas (OECD, 2002; European Environment Agency, 2012). These systems appear to be less vertically integrated and more vulnerable than intensive ones to the emergence of new challenges, such as the consequences of Covid-19 pandemic (Lecegui *et al.*, 2021). Therefore, their continuity in the near future depends on becoming more resilient (Darnhofer, 2021). At the same time that they protect the natural resources, meeting new market and society requirements, may help to increase their resilience. Previous relevant studies have detected the necessity of fulfilling consumer's needs (Coutinho *et al.*, 2021), investigating the differences between consumers and producers in judging meat quality (Sepúlveda *et al.*, 2011; Verbeke *et al.*, 2005). Nevertheless, it is crucial that the actions of the different actors in the value chain are tuned to meet consumer's requirements.

As a general point, differences in quality perception along the value chain have been highlighted in the food literature (Wandel and Bugge, 1997; Djekic *et al.*, 2018). The existence of a certain degree of disconnection between these actors could make consumers not to fully trust in farmers (Cruz *et al.*, 2021). Effective communication should therefore be promoted, which may also strengthen trust and transparency throughout the value chain (Fisher, 2013; Macready *et al.*, 2020).

In this study, we followed a conceptual framework of interrelated categories explaining the sequence of information transference from the cattle farmer to the consumer. As Figure 1 shows, it considers mainly a vertical transference of information through the different stakeholders (Schrobback *et al.*, 2023). However, the farmer may also share information directly with the consumer using alternative channels (e.g., direct sales). The level of complexity of the distribution channel depends on the number of intermediaries. Moreover, a short supply chain may help to diminish the presence of information asymmetry (Schrobback *et al.*, 2023; Cruz *et al.*, 2021), which occurs when the cattle farmer or other actor in the value chain does not effectively share information with consumers about production processes or the beef attributes.

Figure 1 shows a simplified version of the supply chain with a small-medium number of them. In our empirical application, the consumer plays the major role in this framework, and we focus on explaining dark grey areas in Figure 1. We obtained information regarding perceived consumer preferences from all the actors in the value chain aiming at revealing the presence of what can be considered as a perception gap. This gap may exist when there is a difference between own consumers' preferences and what other actors in the supply chain consider consumer preferences are. To the best of the authors' knowledge, there is still a lack of studies in the literature evaluating which are the main beef attributes for consumers at purchasing using this comparative approach.

The right panel in Figure 1 illustrates the dynamic process of consumer perception of food quality (Grunert, 2005). Following Lancaster (1966), consumer perception of food quality is based on their attributes. They have been found to influence this process through the formation of quality expectations at the moment of purchase (Figure 1). This phase can be developed either at the retailer's shop or at a restaurant. Within this step, consumer purchasing motives (including socio-demographics or environmental factors) affect how the

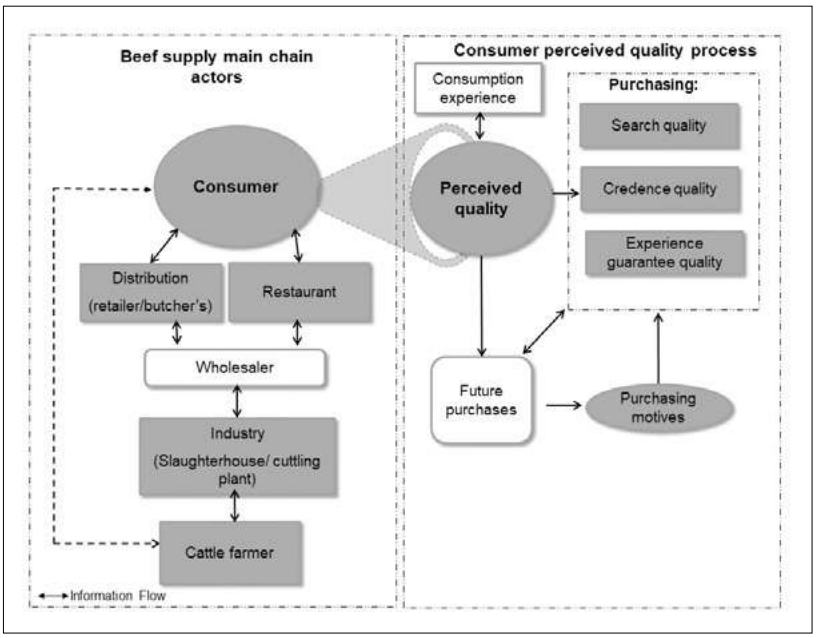

Figure 1 - Simplified conceptual framework to explain the main actors of beef value chain and consumer's perceived quality process.

Source: author's own elaboration based on Grunert (2005), Resano et al. (2018), and Schrobback et al. (2023).

different attributes are perceived. After purchasing, consumers evaluate food by means of the consumption experience (at home/ at a restaurant). A satisfactory result, consistent with the previous expectations, can trigger a future purchase, until becoming loyal to the food product and the establishment.

Food attributes can be classified into search, experience or credence (Nelson, 1970; Darby and Karni, 1973), depending on whether the attribute is evaluated prior to consumption (e.g. price), post consumption (e.g. tenderness), or neither of the above, respectively. However, other actors in the value chain may play a valuable role providing information to the consumer on credence attributes through a certification label, turning the credence attribute into a search attribute. This fact may be useful to diminish the existence of information asymmetry.

Despite its importance (Grunert, 2006), empirical evidence on meat experience attributes is still scarce, as they are more complex and difficult for consumers to evaluate (Aboah and Lees, 2020). Credence attributes, on the other hand have received more attention in the consumer preferences literature (Aboah and Lees, 2020). More specifically, Fernqvist and Ekelund (2014) stated that health-related information and origin are among the main credence attributes valued by consumers. Concerning origin, the sense of belonging to a particular territory may influence how this and other more distant areas are evaluated at the moment of purchasing (Resano and Sanjuán, 2018). In this sense, a strand of the literature deals with 'local' food products (Bernabéu *et al.*, 2020; Fernández-Ferrín *et al.*, 2019; Martínez-Carrasco *et al.*, 2015; Migliore *et al.*, 2017) in the context of geographical and also emotional proximity to the consumer. The interaction of origin and autochthonous breeds, however, is not yet well understood (Resano and Sanjuán, 2018).

The identification of the most relevant beef attributes for consumers at the point of purchase can be obtained through stated and revealed preference methods. Analysing consumers' revealed preferences is costly and infeasible for developing new food products. Therefore, stated preferences have been widely applied (Aboah and Lees, 2020). A rating scale question is the most used stated method. However, in the last decade, choice experiment applications (combining a purchasing context with a controlled experimental setting) have arisen (Hensher *et al.*, 2015). Choice experiments involve the analysis of a smaller number of attributes

to diminish the cognitive effort faced by the consumer, in a more specific choice situation. Despite their peculiarities, it may be interesting to investigate consumer's responses under both approaches, rating and choice experiment, to ensure providing reliable information. The combination of both, may be especially useful for investigating some specific attributes related to key marketing tools; in particular, those whereas the budgetary constraint may be more present in a real purchasing situation.

The main aim of this paper is to identify which are the most important attributes that distinct stakeholders consider that consumers use when purchasing beef, and compare this with consumers' own valuations in order to reveal possible discrepancies or the existence of a perception-gap. For this purpose, consumer preferences are examined under two stated approaches: i) a more convenient rating question and ii) a purchasing context approach within a choice experiment; while consumer preferences according to the different supply chain agents, are examined through a Delphi method. The rest of the paper is structured as follows. Section 2 describes the methodology, whilst the results are discussed in Section 3. Finally, section 4 is devoted to conclusions.

2. Material and methods

2.1. *Consumers' survey*

A face-to-face interview was conducted at the respondents' home. It was carried out in different localities in the Cantabria region in 2015. Out of the 733 participants, 600 fully completed the survey and met the following requirements: they were regular consumers of beef, involved in food shopping and older than 18 years old. A subsample of 504 consumers also participated in the choice experiment. Both samples were representative in terms of age, gender and geographic location (see later Table 4) of the regional population. Further details on the choice experiment can be consulted in Resano *et al.* (2018). The questionnaire was structured in the following order: first, purchasing and consumption habits of beef, and attributes influencing at the moment of purchasing; second, the choice experiment; third, consumer socio-demographics.

The attributes selection criterion in both the questionnaire and the choice experiment was assessed by experts in meat science, on a pilot study with consumers and the relevant scientific literature, as well as based on previous results carried out in the same region (Serrano *et al.*, 2018). In particular, one of the aims of the previous study

Table 1 - Attributes used in the rating question addressed to consumers and experts.

Consumers: At the moment of purchasing beef, how important are the following aspects? Experts or supply chain actors: At the moment of purchasing beef, how important do you consider the following aspects are for consumers? *Please, rate your answers on a scale from 0 (Not at all relevant) to 10 (Very important)*	
Attributes	*Description*
Origin	National production; regional production; regional production with autochthonous breeds
Health-related information	The guaranty of more heart-healthy meat (recommended % saturated/ unsaturated fat and omega-3/6 fatty acids)
Tenderness	The guaranty of a very tender meat
Price	Being cheap or low price
Slaughter age	Beef comes from a young calve (8-10 months)
Colour	The colour is light red/pink
Place of purchase	Establishment appearance
	The butcher's advice

was to obtain meat from a regional origin and autochthonous breed with healthier specific nutritional characteristics, and also very tender.

The full list of attributes evaluated by consumers and experts is shown in Table 1. From this, a subset was used in the choice experiment (see later).

2.2. *Delphi study*

A Delphi survey was conducted to key actors along the beef value chain which we denote as well as "experts". This method has been widely used in social sciences (Landeta, 2006). It has also been demonstrated as especially useful for evaluating the suitability of implementing policy plans and marketing strategies in the agro-food sector. Some relevant applications in the meat sector include Olaizola *et al.* (2012), Chamorro *et al.* (2012) and Tiberius *et al.* (2019).

The Delphi method consists of allowing experts to express their opinion through rounds of interviews in an interactive process employing a feedback system. Thus, the mean results of the first round are revealed to the respondents during the following round to confirm their valuations. The use of two rounds is considered as satisfactory in the literature (Olaizola *et al.*, 2012; Djekic *et al.*, 2018), as it helps getting a certain degree of convergence across the expressed opinions, guaranteeing more the panel participation than with a higher number of rounds (Landeta, 2006; Novakowski and Wellar, 2008).

In our application, the Delphi survey entailed two rounds and was carried out face to face. The second-round questionnaire included a summarized statistical report with both individual and global responses from the first round and invited experts to revise their initial valuation. Finally, the total number of participants was 38, being this number in line with previous Delphi studies (Olaizola *et al.*, 2012; Tiberius *et al.*, 2019). The participating actors can be grouped into four types: cattle farmers (18), industry (3 slaughterhouses and 5 cutting plants), retailers (2 distribution chains and 6 butchers') and restaurants (4). The cattle farmers were recruited in order to capture the diversity in herd sizes (3 had less than 100 Livestock Units (LU), 8 between 50 and 100 LU, and 7 had more than 50 LU) and localisation across the region. Considering the remaining actors, all the slaughterhouses in the region were recruited, the main retailer chain in the region was included as well as a local retailer chain more specialised in local food products; and the butchers and restaurants were recruited upon the condition of distributing local labelled beef. Therefore, we can consider the sample of these actors as representative of the regional value chain idiosyncrasy.

A questionnaire was developed to collect the experts' opinions. This questionnaire enquired among other aspects, which are the main attributes influencing consumers at the moment of purchasing. The proposed attributes were the same as in the consumer questionnaire to ease the comparison between actors (Table 1).

2.3. *Univariate and bivariate non-parametrical analysis*

Respondents (consumers and the remaining actors) were asked to value the degree of importance that the consumers attached to a set of ten attributes at the moment of purchasing beef, using a continuous scale ranging from 0 (Not at all important) to 10 (Very important). Citizens are widely familiar to this scale, since it has been traditionally used in the education system in Spain. Each consumer sample and the population were crossed with information on socio-demographics to test for significant associations through the Chi-square statistic.

The Kolgomorov Smirnov test confirmed that both consumers' and experts' ratings were not following a normal distribution. Then, non-parametrical statistics were used.

The Kruskal Wallis test was performed to investigate whether the ratings differed significantly across attributes, when valued by consumers, and by experts. The Spearman correlation was applied to test the relationship between consumers' and experts' ratings. Finally, the U-Mann Whitney pair-wise comparison test was used to determine which means between consumers and each actor of the beef value chain were different. Analyses have been conducted applying IBM SPSS 26 and Stata 17.

2.4. *The choice experiment*

2.4.1. *The design*

Attributes were selected as explained in subsection 2.1, while only a subset of those presented for evaluation and described in Table 2 were selected for the choice experiment. Note that, in a choice experiment, only a limited number of attributes can be evaluated simultaneously by consumers and that the complexity and number of choice sets to evaluate increases exponentially with the number of attributes. Price levels were obtained from representative retailers, both off and online. The attributes and levels considered in the choice experiment are presented in Table 2.

A sequential and iterative D-efficient experimental design, using a Bayesian approach was applied using Ngene software. A 2-alternative unlabelled design (options A and B) was used and a non-purchase option was also included. A 'pick-one response' was asked, trying to mimic a real-life situation.

Finally, 24 choice sets or cards were obtained split into 3 blocks such as each participant had to make 8 choices. Information on the meaning of the attributes/levels and a description of a purchasing context was read and provided with the cards. Further details on the design can be obtained in Resano *et al.* (2018).

2.4.2. *The econometric model*

The presence of consumers' preference heterogeneity has been captured through a Mixed Logit model (Random Parameters Logit-RPL).

In our specification, the utility obtained by individual n from alternative j (j = 1,…, 3) is modelled as follows (see Table 3 for a description of variables and their abbreviations):

$$U_{jn} = \beta_0 + \beta_{1,n}{}^* HI_j + \beta_{2,n}{}^* CP_j + \beta_{3,n}{}^* CPB_j + \\ + \beta_{4,n}{}^* QT_j + \beta_{5,n}{}^* VT_j + \beta_{6,n}{}^* Pr_j + \varepsilon_{jn} \quad (1)$$

Where β_0 and ε_{jn} are a specific constant (SC) for capturing the average impact of the non-choice, and the residual, respectively. The non-purchase alternative has no specific attribute/levels and its choice is only explained by the specific constant β_0. $\beta_{i,n}$ (i= 1,..., 6) are the random variable coefficients. The researcher has to specify the distribution for these coefficients. In this application, a normal distribution has been chosen, allowing for opposite preferences towards a particular attribute or attribute level. Conditional Logit (CL) is a specific case of a RPL, where coefficients are fixed instead of random. Further details on the RPL and CL models can be obtained from Train (2003) and Hensher *et al.* (2015). Attributes levels have been included in the model as dummies, while price has been incorporated as a continuous variable in (1). Analysis was conducted using NLOGIT 6.0.

Table 2 - Attributes and levels used in the choice experiment.

Attributes	*Levels*
Origin	Other origin; Regional production without autochthonous breeds; Regional production with autochthonous breeds
Health-related information	Absence of information; Recommended % saturated/ unsaturated fat and omega-3/6 fatty acids
Tenderness	Tender; Quite tender; Very tender
Price (Euro/kg)	12, 15 and 18

Table 3 - Description of the explanatory variables estimated in the model.

Name	*Description*
Health_ Information (HI)	1 if the alternative has suitable levels of saturated and unsaturated fat and an adequate proportion omega 3/6; 0 otherwise
Regional_ Production (RP)	1 if the alternative *j* comes from the own region, but is a non-autochthonous breed
Regional_Productionautochthonous Breed (RPB)	1 if the alternative *j* comes from the own region, and is an autochthonous breed; 0 otherwise
Quite_Tender (QT)	1 if the alternative *j* is quite tender; 0 otherwise
Very_Tender (VT)	1 if the alternative *j* is very tender; 0 otherwise
Price (Pr)	Price in alternative *j* with linear effect = 12, 15 or 18 (€/kg)

3. Results and discussion

3.1. *Consumers' profile*

As Table 4 shows, consumers in the survey and the subsample that participated in the choice experiment were mainly living in one out of the six localities with more than 10,000 inhabitants within the Cantabria region (65%), living in a multi-person household (88-91%), mainly female (51%), between 35 and 64 years old (54%), without having reached university studies (79-80%), and with households whose net income was located in the low-medium interval (64-67%).

With regards to some purchasing and consumption habits, consumers interviewed were regular eaters of beef in general, and in particular, 76-78% had consumed beef steak at least once a week at home. Around half of them considered themselves as expert purchasers, ranging from fairly to extremely (51-52%). They purchased beef mainly at the butcher's traditional shop (65%), followed by the butcher's section in the super/hypermarket (24%), and the self-service section in the super/hypermarket (10%). Interestingly, the direct selling channel appears to be marginal. Probably, and among other factors, due to the still low degree of development of this alternative system in Spain compared with other European countries, such as France (Sanjuán *et al.*, 2012). Respondents were also asked to value in a scale ranging from 0 ("I do not trust at all") to 10 ("I totally trust") the degree of confidence they assigned to different sources of information concerning beef origin, production and quality. In particular, more than two thirds of participants assigned a high level of confidence to the butcher's advice. In this sense, 67-69% of participants rated 8 or more out of 10 to this trusted source. This percentage declined to around half of respondents in the case of the producer or distributor source through the label or brand (52-53%), and was slightly lower towards the official bodies through the quality label (48%).

Moreover, approximately half of respondents spontaneously knew endangered autochthonous cattle breeds (46-50%).

The Chi-square statistic did not reveal the presence of statistical differences between-samples ($p<0.05$). Therefore, we may consider that both the full sample and the subsample are statistically homogenous in terms of the main socio-demographics, as well as beef consumption, purchasing habits, trust on information sources and knowledge of local breeds. Furthermore, as Table 4 shows, both samples were not only representative of the population in terms of age, gender and the geographic location, but also in terms of single households and higher education, while the choice experiment subsample is also representative in terms of income. Therefore, both the full and the choice-experiment samples are viewed as fully representative of the Cantabrian population.

3.2. *Main beef attributes influencing consumers' purchase: Consumers' and experts' evaluations*

The results of the Kruskall Wallis test (not presented) revealed statistically significant differences among attributes when valued by consumers (statistic: 389.040; p-value: 0.000) and experts (statistic: 144.935; p-value: 0.000). Considering jointly the ten attributes, the non-parametric Spearman's correlation between consumers' and experts' valuations is weak but positive and statistically significant (statistic: 0.122; p-value: 0.018), what can be interpreted as a sign of certain degree of convergence between the opinions of both groups of actors.

Results presented in Figure 2 (boxplot) and in Figure 3 (average ratings) distinguish between consumers' and experts' ratings.

As Figures 2 and 3 show, statistically significant differences have been found between value chain actors and consumers' valuations in six out of the ten attributes through the Mann-Whitney test ($p<0.05$).

Findings are also revealing the presence of a certain degree of heterogeneity in valuations, especially among consumers. Thus, Figure 2 depicts clearly the presence of a wider range and interquartile range (IR) in consumers' valuations. More specifically, notice that the box, which represents the IR is much longer for consumers than experts. The same occurs with the whiskers, which indicate the range of scores.

Table 4 - Description of the consumer samples and population (Cantabria region).

%	*Full Survey*	*Choice*	*Pop.*[a]	*Chi-square statistics (p-value)*		
				Full Survey vs Choice	*Population (Pop.) versus:* *Full Survey*	*Choice*
Size of the municipality: >10000 inhabitants	65	65	66	0.000 (1.000)	0.022 (0.882)	0.022 (0.882)
Age:				0.000 (1.000)	0.302 (0.860)	0.302 (0.860)
18-34	23	23	25			
35-64	54	54	55			
≥65	23	23	20			
Gender: Female	51	51	51	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)
Household size: One-person	9	12	10	0.479 (0.489)	0.058 *(0.809)*	0.204; (0.651)
Net income:				1.686 (0.430)	11.984 *(0.002)*	5.537 (0.063)
<1150€/month	30	29	26			
1150-3000€/month	67	64	56			
>3000€/month	3	7	18			
Higher education	20	21	18	0.031 (0.861)	0.130 *(0.718)*	0.287 (0.592)
Higher frequency (at least once a week) of beef steaks consumption at home	78	76	-	0.113 (0.737)		
Experience at beef purchasing: Extremely or fairly expert	51	52	-	0.020 (0.887)		
Place of beef purchasing:				0.055 (0.997)		
Butcher's	65	64				
Butcher's super/hypermarket	24	24				
Self-service super/hypermarket	10	11				
Direct selling	1	1				
High degree (8 out of 10) of confidence to the source of information:				0.092 (0.762) 0.000 (1.000)		
Who? How?				0.020 (0.887)		
Butcher's Oral advice	69	67				
Producer/distributor Brand/label	48	48				
Official bodies Quality label	52	53				
Spontaneous knowledge of endangered autochthonous cattle breed	50	46	-	0.321 (0.571)		
N. individuals	600	504	591,888			

[a] *Source: Instituto Cántabro de Estadística (2015a, b, c).*

The consumers distribution appears to be more negatively skewed. In some cases, even the top whisker is not displayed as it coincides with the third quartile. Moreover, statistical results show that the standard deviation is lower in the case of experts (2.22 versus 1.45 for the joint attributes), and the same occurs with the interquartile range (2.98 versus 1.21). In comparison to experts, consumers' ratings are also more extreme (average range of 10.00 versus 5.20 of experts). More specifically, five percent of consumers (percentile 5) did not consider relevant an attribute, as occurred with young calve, while for other five percent (Percentile 95), it appeared to be crucial determining their purchases. Considering these results, in section 3.4 (choice experiment results) we are going to explore the presence of heterogenous preferences in more detail.

From the supply chain actors' perspective, main discrepancies with consumers in terms of ranking occurred with the health-related attribute, butcher's advice, and the low price. Turning to other attributes with a closer ranking across supply chain actors but still with significant mean differences, experts considered that the establishment appearance, as well as the origin, are more important for consumers than what own consumers report. More specifically, heath-related information appeared to be crucial for consumers, whilst it was ranked in the eighth position by experts. This finding is not surprising, as in recent years beef consumers are becoming more health-concerned (Hocquette *et al.*, 2018; Liu *et al.*, 2020). Previous literature supports that the provision of health information is more effective in influencing choice for consumers more health-concerned (Resano *et al.*, 2018). However, value chain actors may not be so conscious of the influence of this attitudinal characteristic on consumer's choice.

Results suggest that attributes related with the beef purchasing establishment (which in our case was mainly referred to the butcher's) were very relevant. This result is at least partially supported; first, by the fact that around two thirds of the consumers who participated in the survey regularly purchase beef at the butcher's, and they stated that they trusted on the advice provided by the butcher; second, by the findings obtained by Resano and Sanjuán (2017), who also found that consumers conferred a high importance to these attributes. However, in our study, the experts expected that establishment attributes were even more important for consumers. Interestingly, the butcher's advice played the most relevant role in consumers' decision from the experts' point of view, while it occupied the fifth position in consumer's mind.

Remarkably, the low price also played an important position (fourth) for experts, but got the last position in consumers' ranking. This result can be specially interesting for determining the suitable pricing strategy. In this sense, Resano and Sanjuán (2017), using a similar rating approach, found that "a higher price" is not perceived as a relevant quality cue at beef purchasing. In our case, despite we were asking for the main attributes, and not the attributes acting as quality cues, results also indicate a low impact of price on preferences. Considering these rating results, and in contrast to value chain actors' opinion, it appears that consumers are not so price sensitive. However, we need to be cautious with this result, since price has been considered within the literature one of the most important search attributes at beef purchasing (Henchion *et al.*, 2014; Aboah and Lees, 2020). Figure 2 also shows the presence of heterogeneous preferences towards price (with a high interquartile range). Therefore, at least some consumers may be prone to purchase a more expensive and differentiated beef (e.g. with the guaranty of very tender beef). Considering its relevance, we are going to further investigate price, since it may exert a higher influence in a purchasing context and when considered simultaneously with other attributes.

Interestingly, both consumers and experts agree on the higher importance of the regional origin over the national one, while value chain actors do not consider this regional origin as important as the consumers claim. The predominant role of the regional origin is well documented in consumer research literature, which is explained by ethnocentrism or cultural-social embeddedness in the territory (Resano and Sanjuán, 2018; Henchion *et al.*, 2014; Aboah and Lees, 2020; Van Ittersum *et al.*, 2003). In our case, the high spontaneous knowledge of endangered autochthonous cattle breed (as shown in Table 4), may

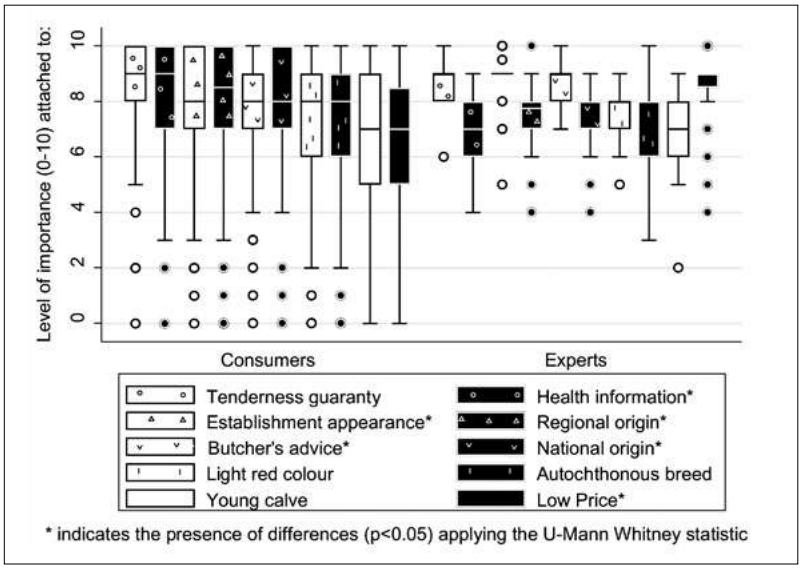

Figure 2 - Importance attached to beef attributes at the point of purchase by consumers, according to consumers and supply chain actors (experts) (boxplot).

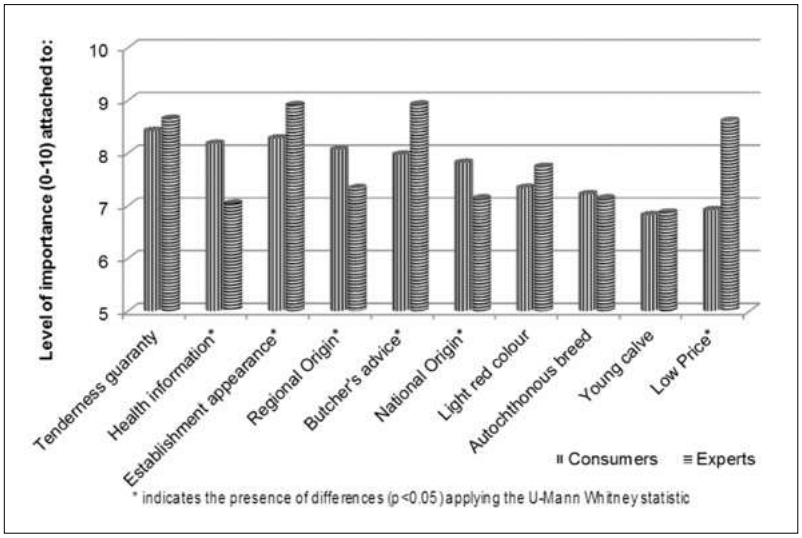

Figure 3 - Importance attached to beef attributes at the point of purchase by consumers, according to consumers and supply chain actors (experts) (mean).

Notes: Items were evaluated through a continuous scale ranging from 0 = Not at all important to 10 = Very important.

be revealing the presence of a strong cultural relationship with the own region. Notwithstanding, specific ethnocentrism indicators could also be evaluated in a future avenue of research.

For the remaining four attributes that do not evoke a distinct response between supply chain actors the total mean can be used as a measure of central position. The tenderness guaranty occupies the first position, followed by the light red colour, autochthonous breed and young calve. Note also that the tenderness guaranty played the most relevant role in determining consumers' choice according to both consumers and experts. This finding agrees with Font-i-Furnols and Guerrero (2014) and Liu *et al.* (2020), who found that tenderness is one of the most valued sensory attributes. The high variability in beef quality makes difficult to assess the eating quality based only on its appearance (Hocquette *et al.*, 2018). The presence of a guaranty may help diminishing the perceived risk that the experienced quality will not match expectations, and the risk of purchasing in general, especially to less expert consumers. Around half of consumers in our study consider

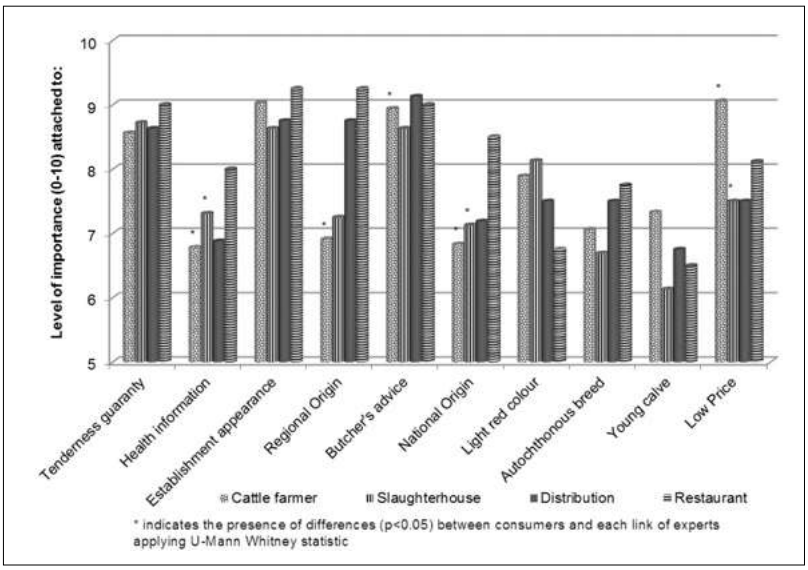

Figure 4 - Importance attached to beef attributes at the point of purchase by consumers, according to different supply chain actors (mean).

themselves as less than fairly experienced (see Table 4), what might explain the high importance attached to the tenderness guaranty, which in turn might increase consumers' confidence at purchasing (Macready *et al.*, 2020).

The remaining attributes with convergent opinions between consumers and experts, the light red meat colour, autochthonous breed and slaughtering young calves played a less prominent role. According to the literature, different shades of red colour may trigger beef freshness perception in a distinct manner (Font-i-Furnols and Guerrero, 2014). In this sense, our result concords with Resano and Sanjuán (2017), who also showed that consumers attached a medium relevance to red colour among a total of 19 quality cues, in particular to a redder one. These authors also reported that consumers assigned a similar importance to the breed and to the slaughter age. Further insights on autochthonous breed are shown in subsection 3.4 when describing the choice experiment results.

3.3. *Main beef attributes influencing consumers' purchase: Different experts' valuations*

After detecting the presence of a certain perception gap, as we have found differences between own consumers valuations and experts' valuations of consumers' preferences, in Figure 4, we are going to analyse which are the most important attributes that distinct actors consider that consumers use when purchasing beef. Following U-Mann Whitney test results, it appears that the closer we move in the value chain to the consumer, the less difference with this actor we find. This result agrees with Cruz *et al.* (2021), who explained that the loss of a direct relationship with the farmer jointly with the current increase in complexity of production and distribution channels, make consumers to obtain relevant purchasing information from actors different from the farmer. Thus, statistically significant differences have been found between cattle farmers and consumers valuations in five out of the ten attributes, while this number decreases to three in the case of slaughterhouses and to zero in the distribution and restaurants stages. In line with our research, Olaizola *et al.* (2012) found the presence of noticeable differences among the different actors of the beef value chain. Nevertheless, they showed the presence of higher convergence between those actors placed farther from the consumer. In particular, differences between consumers and farmers were lower than between others actors of the value chain in some specific attributes, such as animal nutrition and quality certification.

Concerning the ranking, as mentioned in the previous subsection, main discrepancies with

consumers occurred with the attributes related to health-related information, butcher's advice and low price. The former appeared to be crucial for consumers, whilst it was ranked from the fifth position in the case of slaughterhouse to the last position by cattle farmers. As we may expect, the second aforementioned attribute played the most relevant role for distributors, however, no significant differences were found with consumers. In contrast, significant statistical differences were found in the case of cattle farmers, where it occupied the third position versus the fifth position in consumer's mind. The low price played the most relevant role for the cattle farmer, getting the fourth position for the slaughterhouse, and the last one in consumers' ranking.

Similarly to consumers, cattle farmers also conferred a higher utility to the regional origin than the national one (eighth versus ninth position). However, the consumer attached a higher utility in both cases (assigning the fourth and sixth position, respectively).

3.4. *Main beef attributes influencing consumers' purchase: Consumers' choice experiment results*

In this subsection we further examine consumers' preferences. For comparison purposes with the stated questionnaire approach, we investigate the relative importance attached to the different beef attributes obtained from the choice experiment, that is, in a simulated purchase context. Obviously, only that subset of attributes within the choice experiment can actually be compared across methodological approaches.

Estimation results are showed in Table 5. The Adjusted Pseudo R^2 in both models (0.330 and 0.351 in CL and RPL respectively) depicts that the overall fit can be considered as appropriate. Nevertheless, the most flexible model (RPL), which allows capturing consumers' preference heterogeneity, provides a better fit. Similarly, the likelihood ratio test (LLR) favours the random versus the fixed parameters specification.

Mean coefficients are positive and highly significant, except price. This fact implies that providing information about some attribute levels to the consumer at the moment of purchasing increase the probability of choosing a product with these features. Considering the RPL results, standard deviations are significant (apart from regional production and quite tender meat), what is an indication of heterogeneous preferences. Therefore, subsequent analysis will be based on the RPL estimation.

In particular, the price effect is negative and significant with a significant standard deviation. Given the normality assumption, the probability of choice increases when the price is lower for around 52% of the respondents, while the remaining 48% prefer a higher price. This latter result can be indicating that price may be acting as a quality cue (Resano *et al.*, 2012). However, on average, this effect is almost compensated. This result agrees with the high standard deviation and interquartile range found by the low-price evaluation in the consumer survey (see subsection 3.2). It may also help to explain, at least to a certain extent, the last position occupied by low price in the ranking of attributes relevance, suggesting that for some consumers a low price is not so relevant at the moment of purchasing. Previous studies also showed the existence of heterogeneous preferences towards price (Sanjuán and Khliji, 2016), as well as consumers' segments with opposite preferences concerning this attribute (Font-i-Furnols & Guerrero, 2014).

The relative importance of each attribute is shown in Table 6. The health-related information ranks first (33%), followed by origin (31%). The tenderness level occupies the third place (21), and finally, price gets the last place (15%).

The relative importance for the selected attributes obtained from the choice experiment and that one observed with the attribute ratings in the survey are in general consistent, with minor discrepancies. Thus, the relevance of health-related information is highlighted by both methods, occupying the first position in the ranking, while a low price is considered as the least important in both methods. Likewise, the regional origin is preferred over the remaining origins or the national one in both methods used to elicit preferences. The tenderness guaranty, on the other hand, appears to be more important in the rating question than in the choice experiment, whilst the regional autochthonous breed occupies a

Table 5 - Conditional and Random Parameters Logit results.

Variable		*CL[a]: Coefficients (Std. Error)*	*RPL[a]: Coefficients (Std. Error)*
Health_Information$_j$ (HI)	Mean	0.963***[b] (0.052)	1.380*** (0.093)
	Std.Dev.	-	1.245*** (0.097)
Regional_Production$_j$ (RP)	Mean	0.563 *** (0.050)	0.746***(0.063)
	Std.Dev.	-	0.051(0.130)
Regional_Production_ Autochthonous Breed$_j$ (RPB)	Mean	0.934*** (0.058)	1.286***(0.086)
	Std.Dev.	-	0.969***(0.097)
Quite_Tender$_j$ (QT)	Mean	0.414*** (0.052)	0.614*** (0.065)
	Std.Dev.	-	0.120(0.118)
Very_Tender$_j$ (VT)	Mean	0.634*** (0.056)	0.895***(0.085)
	Std.Dev.	-	0.901***(0.102)
Price$_j$	Mean	-0.057*** (0.008)	-0.107***(0.013)
	Std.Dev.	-	0.163***(0.012)
SC	Mean	1.971*** (0.140)	3.832***(0.242)
LL0[c]		-3368.673	-3368.673
LL[c]		-3136.930	-2867.475
LLR[d]		463,486 (0.000)	538,910 (0.000)
Adjusted Pseudo – R^2		0.330	0.351
N. observations		4032	4032

[a] *Models were estimated using 200 Halton draws.*
[b] **** indicates the presence of statistical significance at 1%.*
[c] *LL0 and LL account for the value of the log-likelihood function evaluated in a model with constant, and with all the explanatory variables, respectively.*
[d] *LLR to test the joint significance of CL model, first versus the model with only a constant, and second, versus the RPL model (p-value in parentheses).*

more relevant position according to the latter experiment. These results appear to indicate that adding degrees of reality to the experiment may not always affect noticeably the ranking of preferences, being consumers' preferences consistent. Nevertheless, further research is still needed to ascertain the suitability of including a purchasing context when evaluating consumer rated preferences.

4. Conclusions

The European public administration is encouraging the development of healthier, fairer and more environmentally friendly beef production systems. In the same line, consumers are becoming more concerned about these characteristics.

Table 6 - Attributes/levels relative importance calculation.

Attributes/levels	*Effect*	*Max e[a]*	*Ri[b]*	*Rank*
Health Information	1.380	1.380	33%	1
Origin	1.286	1.286	31%	2
Tenderness level	0.895	0.895	21%	3
Price	-0.107	0.642	15%	4

[a] *Following Maaya, Meulders, Surmont & Vandebroek (2018), for instance the maximum effect (Max e) of the price in the CL model is the absolute value of its estimate multiplied by the range or difference between the highest and lowest levels of the price: 0.107*(18-12) =0.642.*
[b] *Relative importance (Ri) for each attribute or level is calculated as the ratio between its range and the sum of ranges for all the attributes or levels (see also Sanjuán and Resano, 2020).*

However, some communication failures may exist along the beef chain preventing from a suitable transmission of real consumer requirements to the remaining actors. Thus, the rationale behind our approach responds to reduce the perception gap between the different actors in the value chain in order to meet more efficiently consumer preferences regarding meat attributes at the moment of purchase. Despite its relevance, this issue has still been scarcely analysed within the literature. To accomplish this aim, this paper compares own consumers reported preferences with the opinion that different actors along the value chain have on consumer's preferences. Furthermore, consumers responses are obtained under two stated approaches: a rating scale and a choice experiment.

The main beef attributes at the point of purchase for consumers were tenderness, health information and the regional origin. In general terms, consumers did not appear to search for low-price beef at purchasing, however, heterogenous preferences towards price have been found. These findings may be revealing the existence of a niche market for more differentiated and sustainable beef. This information may be especially interesting for cattle farmers producing local or autochthonous breed calves in extensive livestock farming systems, as they could be more vulnerable to the emergence of the recent challenges. These actors should therefore put a greater effort not only on producing very tender and healthy beef, but also on providing information of this added value along the value chain in order to finally meet consumers' preferences.

However, some discrepancies have been found between the different actors throughout the beef chain. In this sense, results suggest that cattle farmers appear to know less about consumers' preferences than the remaining actors. This finding demonstrates to marketers and policy makers the importance of transmitting consumer needs along the whole supply chain, especially to those actors who are located upstream of the supply chain. Based on the results of the research, local and national institutions should work together with the remaining actors within the chain to improve the communication and promote the consumption of sustainable beef. In this sense, the development of a marketing campaign to promote the use of a voluntary and sustainable labelling, as occurs with the autochthonous breed, and with an EU origin-labelled scheme, could be advisable. This labelling adds utility to the consumer, and it is useful to diminish the existence of information asymmetry about the production processes, and the beef attributes, especially between the cattle farmer and the consumer.

Moreover, encouraging the development of short-supply chains may also help to establish a closer relationship between producers and consumers and shorten the perception gap. This cooperation may enable the participants to strengthen the trust and transparency throughout the value chain.

Furthermore, we have analysed the results obtained using a convenient and easy attributes-rating question and the ones obtained within a choice experiment, which mimics a real purchase, although without an economic incentive. Despite the presence of some differences, which may be explained at least partially by their specificities, preferences elicited through both approaches appear to be mostly consistent. Therefore, we can conclude, that conducting a stated rating approach provides a consistent ranking of relevant consumers preferences, which can be a very useful tool in the comparison of the different actors' valuations throughout the value chain. Moreover, further insights should be provided to assess to what extent hypothetical methodologies may be good predictors of a real purchase.

Future extensions of this study may be based on exploring different markets. For instance, comparing the results obtained in one of the main producing areas with a less producing area. Additionally, investigating different methodological refinements may be also interesting. More specifically, it could be interesting to investigate the effect of turning the stated method into an experiment closer to an actual purchase.

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Impact of social expenditures on multidimensional poverty in Turkey

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Abstract

Reducing poverty is a critical priority for developing countries. Despite the government allocating approximately 13% of the GDP to social support expenditures, poverty affects around 15% of the population in Turkey. However, there is a need for more research that measures the effects of social expenditures, which is a fundamental tool in the fight against poverty, while also considering the current developments in poverty measurement methods. This study aims to measure the impact of social support expenditures on poverty in Turkey. The study compares a multidimensional poverty approach to a one-dimensional approach. The effects of social support expenditures on households in Turkey were analyzed using econometric methods. The study finds that multidimensional poverty values are approximately 2.5 times higher than one-dimensional values. Government spending was found to have no impact on multidimensional poverty, while private expenditure had a relatively minor impact. The paper concludes by discussing the inefficiency and ineffectiveness of government social expenditures in Turkey.

Keywords*: Poverty measurement, Multidimensional poverty, Turkey, Social expenditures*

1. Introduction

In the recent past, research on the measurement of poverty has come to a point where poverty is considered a multidimensional phenomenon that requires to be measured accordingly. The "Multidimensional Poverty Index" (MPI) developed on this basis can be considered as an extension of the discussions by Amartya Sen from the 1970s and the approach put forward by the Foster-Greer-Thorbecke (FGT) approach in 1984. However, the foundations of the approach can be said to have been laid in Alkire (2007) and Alkire and Foster (2011). The approach developed by Alkire-Foster has quickly gained an important place in the literature (Arndt *et al.*, 2012; Batana, 2013; Battiston *et al.*, 2013; Foster and Horowitz, 2012; Gradín, 2013; Nicholas and Ray, 2012; Notten and Roelen, 2012; Nussbaumer *et al.*, 2012; Seth and Santos, 2018; Seth and Villar, 2017; Tonmoy Islam, 2014). Due to the specific sociological, historical, and other characteristics of different countries, poverty research conducted in various places through this approach has both contributed to the method and expanded its use.

Researches aiming to measure poverty through the multidimensional approach are quite new in Turkey. Calculation of multidimensional poverty in Turkey in the same way as Alkire-Foster did caused some specific problems from the point of missing or defective data, as it was the

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case for many other countries. For this reason, there were studies that used the Alkire-Foster approach in the calculation of Turkish MPI but suggested various adaptations. Acar and Başlevent (2014) calculated the Turkish MPI values for the period between 2007 and 2010 in 4 dimensions and for 15 indicators, including 4 indicators in the housing dimension and 2 indicators in the labour market dimension, in which they did not include the education dimension. On the other hand, Uğur (2015) calculated the Turkish MPI values only for the year 2010 in 3 dimensions and for 14 indicators in total, including 2 indicators in the Education and health dimension, 6 indicators in the Economic conditions and assets dimension, and 6 indicators in the Housing and living standard dimension. Similarly, Karadağ (2015) calculated the Turkish MPI values for the period between 2006 and 2012 with 4 indicators in the Basic Consumption dimension, 2 indicators in the Education dimension, 3 indicators in the Health dimension, 3 indicators in the Employment dimension, and 4 indicators in the Housing conditions dimension. Limanli (2016) calculated the Turkish MPI values for the period between 2006 and 2012 with 1 indicator in the Income dimension, 1 indicator in the Education dimension, 2 indicators in the Health dimension, 3 indicators in the Environmental Problems dimension, and 1 indicators in the Time dimension. Karahasan and Bilgel (2021) calculated the Turkish MPI values for the period between 2014 and 2017 with 7 indicators in the Housing dimension, 4 indicators in the Environment dimension, 2 indicators in the Education dimension, and 3 indicators in the Health dimension.

In this study, the authors also made a "Multidimensional Poverty" measurement for Turkey with certain improvements, including a wider period of measurement (2006-2016) and a higher number of indicators as much as allowed by the scope of the data set used.

In the study, in addition to the multidimensional measurement of poverty, social expenditure policies were also analyzed as one of the most important policy instruments of governments in their poverty reduction efforts. The literature on economics is quite rich in terms of research that tries to analyze the impacts of social expenditures on poverty. However, those researchers generally used poverty approaches far from being multidimensional, and they most of the time focused on different types of social expenditures. The literature mainly contains studies that compared different types of social expenditures (government or private, in kind or in cash, etc.) (Chen *et al.*, 2017; Gibson *et al.*, 2011; Khera, 2014; Lusk and Weaver, 2017; Maitra and Ray, 2003; Miller and Neanidis, 2015; Mitrut and Wolff, 2011; Nikolov and Bonci, 2020; Olinto and Nielsen, 2007; Payne, 1998), analyzed the impacts of social expenditures on a specific area (Barrientos and DeJong, 2006; Gertler, 2000; Ozturk and Kose, 2019; Sadoulet *et al.*, 2001), or analyzed the impacts of social expenditures on values calculated through one-dimensional poverty approaches (van de Berg and Cuong, 2011; Ertekin and Hayat, 2022; Jalan and Ravallion, 2000; Lloyd-Sherlock, 2006; Sarisoy and Koç, 2010). Notwithstanding a large amount of literature about the impact of social expenditures on poverty, relatively little attention has been paid to studying the new methods of poverty measurement. Thus, this study can be shown as one of the few pioneering researchers in the field.

The main purpose of this article is to analyze the effectiveness of social support programs in reducing poverty in Turkey. To achieve this goal, the article takes into account the latest developments in the field of poverty measurement. This sets it apart from previous studies analyzing social support expenditures based on a one-dimensional poverty approach for Turkey. The analysis reveals results that are significantly different from previous studies conducted by Ertekin and Hayat (2022) and Sarisoy and Koç (2010). This study demonstrates that when analyzing the effects of social assistance on poverty from a multidimensional perspective, the problems in the system become more evident. By taking a multidimensional approach to poverty, this research highlights how the shortcomings of the system become clearer when evaluating the impact of social assistance programs.

Finally, this study has made a two-way contribution to the literature: (1) Contribution was made to the adaptation of a "Multidimensional Poverty Index" calculation method specific

to Turkey as a developing country, and (2) the impacts of social expenditure policies on multidimensional poverty were tried to be analyzed for the first time. Thus, a new analysis and data source was established for policymakers to combine the recent developments in poverty measurement with the sociological structures specific to a country.

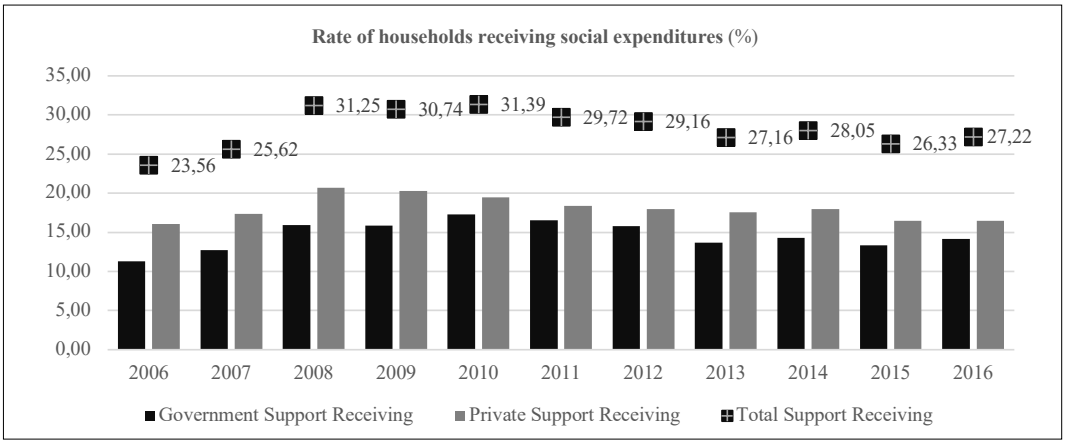
2. Social expenditures system in Turkey

Social expenditures have been an important part of the Turkish economy recently. The share of social expenditures in Turkish GDP increased from 10.76% to 12.83% between 2006 and 2016 (TUİK, 2018). In parallel, the rate of families receiving social expenditures also increased in the same period. As can be seen in Figure 1, the rate of families receiving social expenditures rose from 23.5% in 2006 to 31.2% in 2008, the year in which the international financial crises erupted, maintained at the same level in 2009 and 2010, and then fell into a decline, decreasing to 27.2% as of 2016.

Social expenditures in Turkey can be analyzed into two distinct groups government and private social expenditures. In modern terms, the government social expenditure system of Turkey started to emerge in the 2000s (Bugra, 2008). In 2004, the Directorate General for Social Supports and Solidarity was established under the Prime Ministry to coordinate the social support efforts made with the World Bank. This institution was subsequently transformed into the Ministry of Family and Social Policies, which meant the establishment of a social expenditures system at the ministry level for the first time in 2011. The name of the Ministry of Family and Social Policies was changed to the Ministry of Family, Labour, and Social Services (MoFLSS) in 2018.

The rate of citizens who benefit from government social expenditures increased from 11.32% to 14.18% between 2006 and 2016. These social expenditures can be listed as Patient care, Disability benefits, Pensions, Widows and orphans benefits, Family and child benefits, Unemployment benefits, Social exclusion benefits, and Administrative expenses. Citizens need to fulfill the necessary bureaucratic requirements to become eligible to receive these government social expenditures. The basic condition for becoming eligible for these social expenditures is the submission of the documents (medical reports, insurance records, etc.) demanded by public institutions to the relevant ministries. After an application is made by an individual, social expenditures investigation officers carry out household investigations and social circle investigations, and they analyze certain case-specific conditions to decide whether the individual is eligible to receive social expenditures. While these social expenditures are provided in cash most of the time, there are also in-kind expenditures provided by the government.

Figure 1 - Rate of households receiving social expenditures (%).



Source: The micro data set by Turkish Statistical Institute's (TUİK), income and living conditions research.

In addition to the government social expenditure system that has been established and developed in the last 20 years, private social expenditures have also been important for the Turkish people. As can be seen in Figure 1, the rate of households benefiting from private social expenditures increased from 16.07% to 16.50% between 2006 and 2016, which is higher than the rate of households receiving government social expenditures. The main reason for this is the private social expenditure network specific to Turkish society, resulting from the traditions of centuries. Private social expenditures are an area where non-governmental actors play an effective role through various motives, including kinship relations and philanthropy (Bugra and Candas, 2011).

3. Data and methodology

3.1. *Data*

The micro-sectional data set of the income and living conditions research

The main data set used in the study was the micro-sectional data set of the income and living conditions research, which is regularly collected by the Turkish Statistical Institute (TUİK) on an annual basis. The main purpose of the collection of this data set is to determine household income and assets and the income-based poverty threshold. The households to be surveyed are selected to represent the prevailing circumstances in the country, and they are changed on a monthly basis. The sampling unit preferred for representation purposes is the household. The data set mainly consists of two parts defined as households and individuals. The household data include detailed variables related to household assets and other variables such as disposable income. The individual data, on the other hand, consist of socio-economic variables, including the ages, sexes, educational levels, and employment statuses of persons in the household, and their incomes and the sources of such incomes. The micro-sectional data set of the income and living conditions research was preferred as the data set to be used in this study since it represents the whole country, includes a relatively large population, and offers detailed and comprehensive income and asset data for both households and individuals.

The micro-sectional data set of the income and living conditions research was utilized in this study, encompassing the period from 2006 to 2016. This dataset was utilized since the statistical data used in Turkey was first published in 2006. The data set includes details about 177,162 Turkish households in total. The scope of this study included three main sections. The first one was the calculation of income-based one-dimensional household poverty values. The second was the multidimensional household poverty values calculated on the basis of household employment, health, education, and assets. The third was the econometrical analysis for which various variables, including but not limited to the social expenditures provided by the government and non-governmental actors, region of residence, and educational level of the household head, were used.

The term "household income" refers to the annual disposable income of a household. In the analysis of the variables effective on the multidimensional poverty values of households, household income was studied in three categories as government social expenditures, private social expenditures, and household income without social expenditures. All monetary values, including income, were transformed into fixed prices by applying TUİK's Consumer Prices Index (2003=100), and all calculations were made based on these fixed values

The statistics for the variables used in this study are presented in Table 1. These variables were determined by examining previous research in the literature (Van den Berg and Cuong, 2011; Chen *et al.*, 2017; Gibson *et al.*, 2011; Mitrut and Wolff, 2011; Sarisoy and Koç, 2010; Waidler *et al.*, 2017). These variables will be used in the subsequent sections of the study for the analysis.

3.2. *Methodology*

One-dimensional poverty measurement

Before the emergence of the multidimensional approach, the methods most widely used in the measurement of poverty were the one-dimen-

Table 1 - Descriptive analyses.

Variables	*Description*	*Avg.*	*SD*
Income w/o social expenditures	Annual household income (excluding social expenditures) (TL 1,000)	33.59	28.60
Government social expenditures	Annual government household social expenditures (TL 1,000)	0.18	0.77
Private social expenditures	Annual private household social expenditures (TL 1,000)	0.87	3.39
Household size	Number of household members	2.69	1.26
Household size^2	Square of the number of household members	8.94	9.85
Age	Age of the household head	48.95	15.10
Age^2	Square the of the household head	2609.97	1578.74
Occupation	1 if there is anyone employed in the agricultural industry, otherwise 0	0.16	0.37
Education	The educational level of the household head	-	-
	Illiterate	-	-
	Literate	0.07	0.26
	Primary school	0.44	0.50
	Secondary school	0.10	0.31
	High school	0.08	0.27
	Technical high school	0.08	0.27
	University	0.13	0.33
MPI	Multidimensional poverty index	0.41	0.17
Asset tax	1 if at least one household member pays taxes for assets; otherwise 0 (house, car, etc.)	0.55	0.50
Student	1 if there is at least one household member studying, otherwise 0	0.23	0.42
Year control	Dummy variable for 11 years (except the first year)	-	-
Region control	Dummy variable for 11 geographical regions (except Istanbul)	-	-

Source: Calculated from the micro data set by Turkish Statistical Institute's (TUİK), income and living conditions research.

sional (monetary) methods. The one-dimensional (monetary) methods can be classified into two income-based and expenditure-based methods. In the one-dimensional (monetary) approach, different from the multidimensional approach, equivalence scales are used. The equivalence scale is an index that converts the current income or expenditure of a household into data comparable to household wealth levels (FAO, 2005) and allows them to be compared with the wealth level of a reference household. It is mainly based on consumer theory and economies of scale (Rio Group, 2006).

In scientific research and governmental calculations in Turkey, the equivalence scale called the OECD scale is used. This scale was developed by Hagenaars *et al.* (1994) (Chanfreau and Burchardt, 2008), in which the value attributed to the household head is 1, while the values attributed to each additional adult and child household member are 0.5 and 0.3 respectively (OECD, 2012). The scale defines an adult as an individual at the age of 14 or higher.

In this study, the OECD equivalence scale was used for calculating the one-dimensional poverty values. Under the same method, half of the equivalent disposable income of a household was calculated as the poverty threshold. The rate of the number of households with income lower than this threshold in total number of households was determined as the poverty rate for the relevant year.

Multidimensional poverty measurement

The literature includes many researches that used the Alkire and Foster (2011) approach (Acar and Başlevent, 2014; Booysen *et al.*, 2008; D'Ambrosio *et al.*, 2011; Licona, 2016). However, the information about the indicators selected for the implementation of the approach is not available for every country. For this reason, researchers tended to define substitute dimensions and indicators for their own research areas (Acar and Başlevent, 2014; Asselin and Vu, 2008; Bérenger and Verdier-Chouchane, 2007).

In this study, the multidimensional poverty index values of Turkey were calculated for the period between 2006 and 2016, with 4 different dimensions and 17 indicators. The indicators used, their weights, and their average and standard deviation values in the period of study are

Table 2 - The indicators used in multidimensional poverty calculation.

Dimensions	*Indicators*	*Description*	*Weight*	*Average*	*SD*
Economic conditions and assets	Hot water	1 if the household does not have access to hot water, otherwise 0	1/28	0.20	0.40
	Washing machine	1 if the household does not have a washing machine, otherwise 0	1/28	0.07	0.26
	Meat, chicken or fish consumption	1 if the household cannot consume meat, chicken or fish every two days; otherwise 0 (meat equivalents for vegetarians)	1/28	0.51	0.50
	Unexpected costs	1 if the household cannot cover unexpected costs, otherwise 0	1/28	0.52	0.50
	Heating	1 if the household cannot heat the house, otherwise 0	1/28	0.28	0.45
	New cloths	1 if the household cannot buy new clothes, otherwise 0 (other than second-hand clothes)	1/28	0.35	0.48
	Crime and violence in the neighborhood	1 if there is widespread crime and violence in the neighborhood, otherwise 0	1/28	0.10	0.30
Housing	Having a bathroom in the house	1 if there is no bathroom in the house, otherwise 0	1/20	0.06	0.24
	Having a toilet in the house	1 if there is no toilet in the house, otherwise 0	1/20	0.12	0.33
	House payments	1 if house payments (rent, housing loan, etc.) cannot be made regularly, otherwise 0	1/20	0.82	0.38
	Non-house payments	1 if non-house payments cannot be made regularly, otherwise 0	1/20	0.55	0.05
	Construction problems of the house	1 if there are problems such as a leaking roof, damp walls, or ruined windows, otherwise 0	1/20	0.40	0.49
Education and health	Chronic health problems	1 if there is at least one household member with a chronic disease, otherwise 0	1/12	0.40	0.49
	Health problems in the last 6 months	1 if at least one household member had a health problem preventing his or her daily activities in the last six months, otherwise 0	1/12	0.48	0.50
	Literacy	1 if there is at least one illiterate household, otherwise 0	1/12	0.27	0.44
Employment	Unemployment	1 if there is at least one unemployed household member who is able to work, otherwise 0	1/8	0.70	0.46
	Informal employment	1 if there is at least one informally employed household member, otherwise 0	1/8	0.36	0.48

Source: Calculated from the micro data set by Turkish Statistical Institute's (TUİK), income and living conditions research.

presented in Table 2. It should be noted that certain sociological characteristics of Turkish society were taken into consideration in the selection of indicators under the defined dimensions. For example, Turkish households are known to consider washing machines among the basic household goods. Thus, the absence of this asset in a household was reflected in the calculations. Similarly, in addition to the consideration of unemployed household members, any informal workers were also evaluated since informal employment is quite widespread in Turkey. In the data set used for the study, it is stated that there was at least one informally employed person in at least 37% of the households as of the period of data collection. In particular, informal employment is quite common among migrants whose population gradually increases in recent years (ILO, 2015). The indicators that were not included in the MPI were also addressed based on the same sensitivity. For example, the house floor construction indicator, widely used in the international literature, was not included in the calculations for Turkey since Turkish culture favors the use of carpets. Especially in the eastern provinces of Turkey, families do not prefer to renew floor structures even if they have adequate financial resources, and they instead use various types of carpets.

Impacts of social expenditures

If we assume that a household wants to maximize its wealth, the household problem can be formulized as follows (Maitra and Ray, 2003)[1] for cases where the household has only one decision-making unit or the household members agree on a common decision (Sadoulet and De Janvry, 1995):

$$W = W[\{U(x; Q, e)\}] \tag{3.1}$$

Here W represents wealth, U represents a benefit, x represents consumption on which benefit depends, Q represents household characteristics, and e represents the characteristics of the decision maker (generally the household head). The purpose of the household is to maximize W. However, various points, including income and time constraints, should be taken into consideration in this maximization and the point on which this study focuses is income constraint. This constraint can be presented as follows:

$$p'x = \sum_{r=1}^{3} I_r \tag{3.2}$$

Here, p represents goods price, I represents income, and r represents source of income. For the purposes of this study, the important item is the source of income which consists of three elements classified as government transfers, private transfers and other income (r=1, 2, 3).

The main focus of this study is the relationship between the different sources of income (I_r) and their impacts on multidimensional poverty. The main question needed to be considered from the point of the econometric measurement of such impacts is the endogeneity problem arising from the simultaneous bias between income and poverty. This problem arises due to the fact that social expenditures and household poverty have mutual effects on each other. Social expenditures are generally provided to poor households, which means that social expenditures are not provided randomly and poorer households have a higher probability of receiving social expenditures. On the other hand, social expenditures contribute to the level of wealth of a household, pointing to a simultaneous bias between social expenditures and poverty.

The problem of endogeneity has been dealt with in the literature in research on poverty and income (Giannetti *et al.*, 2009; Hagen-Zanker and Leon Himmelstine, 2016; Jensen, 2004), while the subject has been addressed indirectly due to the difficulty in finding suitable instrumental variables. In this study, as was done in the research by Maitra and Ray (2003) and Chen *et al.* (2017), the relationships between different income sources and, in particular, between social expenditures and poverty were dealt with through the three-stage least squares (3SLS) method.

[1] Maitra and Ray (2003) expressed the non-integrated household in their model presentations, while this study addresses the integrated household and it benefits only from the model presentation of the referenced research.

Here, the relevant equation system is put forward as follows[2]:

$$Y^h = f_1(Q_1^h, e_1^h, z_1^h; \beta_1) + u_1^h \quad (3.3)$$

$$S^h = f_2(Y_2^h, MPI_2^h, Q_2^h, e_2^h, z_2^h; \beta_2) + u_2^h \quad (3.4)$$

$$R^h = f_3(Y_3^h, S_3^h, MPI_3^h, Q_3^h, e_3^h, z_3^h; \beta_3) + u_3^h \quad (3.5)$$

$$MPI^h = f_4(Y_4^h, S_4^h, R_4^h, Q_4^h, e_4^h, z_4^h; \beta_4) + u_4^h \quad (3.6)$$

Here, MPI represents the multidimensional poverty index, S and R represent the government and private transfers respectively, Y represents income without social expenditures, Q represents household-specific variables, e represents individual-specific variables, z represents other control variables (such as years and region dummies), and u represents the error term. As can be seen in the equation system, social expenditures have an impact on the poverty level of households (equation 6) and vice versa (equations 4 and 5).

4. Result

4.1. *Comparison between one-dimensional poverty and multidimensional poverty in Turkey*

One-dimensional and multidimensional poverty values in Turkey were calculated as explained in the methodology section. The changes in these values over the years and for the selected variables are presented in Table 3 and Table 4 for one-dimensional and multidimensional poverty respectively. It is seen that one-dimensional poverty fell from 0.19 to 0.14, while multidimensional poverty fell from 0.46 to 0.38 between 2006 and 2016 in Turkey. As expected, these poverty values vary over the years and depend on region, household size, educational level and employment status. In almost all variables, multidimensional poverty values are higher than one-dimensional poverty values (around 2.5 times).

In Turkey, both one-dimensional and multidimensional poverty values increase from the east to the west. For the year 2016, while both approaches found Istanbul as the region with the lowest level of poverty, the second wealthiest region of the country was found to be Western Marmara in the MPI approach and Eastern Marmara in the one-dimensional poverty approach. Another important discrepancy between the results of the two approaches is about the poorest region of the country. For the year 2016, the poorest region of Turkey was Northeast Anatolia according to the MPI approach, although it was Southeastern Anatolia according to the one-dimensional poverty approach. While the difference between Northeastern Anatolia, the poorest region, and Southeastern Anatolia, the second poorest region, was quite small according to the MPI approach (0.47-0.45=0.02), the difference between Southeastern Anatolia as the poorest region and Northeastern Anatolia as the second poorest region was relatively higher according to the one-dimensional poverty approach (0.38-0.23=0.15).

The poverty values calculated based on the household size variable are similar in the one-dimensional and multidimensional approaches and the results suggest that the level of increases in parallel with household size, the only exemption to which are single-person households. According to the one-dimensional approach, for the year 2016, the poverty value of single-person households was higher when compared to two-person households (0.12>0.10). However, when the MPI values for single-person and two-person households are compared for the same year, it is seen that they are higher for two-person households (0.33>0.32).

The one-dimensional and multidimensional approaches generated similar results for the education variable, according to which the higher the educational level of the household head, the lower the poverty value of the household. However, under the education variable, the main difference between the two approaches manifested itself in households with a head who had a university or higher education. Although these households had the lowest poverty values in both approaches in all years of study, their pov-

[2] The time index t is not included for ease of presentation.

Table 3 - One-dimensional poverty values in Turkey.

Variable / Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*Average OPI*
Region												
Istanbul	0.03	0.01	0.03	0.03	0.04	0.03	0.04	0.03	0.03	0.04	0.03	0.03
Western Marmara	0.13	0.11	0.11	0.14	0.13	0.11	0.13	0.09	0.09	0.12	0.09	0.11
Aegean	0.12	0.10	0.10	0.09	0.09	0.09	0.09	0.07	0.07	0.08	0.08	0.09
Eastern Marmara	0.07	0.05	0.05	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.06
Western Anatolia	0.10	0.07	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.07
Mediterranean	0.23	0.22	0.16	0.17	0.13	0.16	0.18	0.16	0.18	0.17	0.16	0.17
Central Anatolia	0.13	0.15	0.16	0.19	0.16	0.15	0.14	0.13	0.12	0.12	0.14	0.14
Western Black Sea	0.21	0.15	0.15	0.16	0.15	0.12	0.10	0.10	0.10	0.11	0.09	0.12
Eastern Black Sea	0.11	0.09	0.11	0.11	0.11	0.10	0.11	0.07	0.09	0.10	0.09	0.10
Northeastern Anatolia	0.35	0.29	0.31	0.35	0.32	0.31	0.35	0.35	0.30	0.28	0.23	0.31
Eastern Anatolia	0.36	0.35	0.33	0.40	0.35	0.36	0.38	0.33	0.33	0.32	0.27	0.34
Southeastern Anatolia	0.55	0.52	0.47	0.49	0.46	0.47	0.46	0.45	0.40	0.37	0.38	0.44
Household size												
1	0.15	0.12	0.10	0.13	0.12	0.12	0.13	0.12	0.12	0.12	0.12	0.12
2	0.17	0.14	0.14	0.15	0.13	0.13	0.13	0.12	0.12	0.11	0.10	0.13
3-5	0.19	0.17	0.18	0.19	0.18	0.17	0.19	0.17	0.17	0.17	0.15	0.17
5+	0.37	0.34	0.35	0.41	0.43	0.44	0.43	0.39	0.37	0.39	0.33	0.39
Educational level of household head												
Illiterate	0.40	0.35	0.36	0.40	0.36	0.37	0.37	0.32	0.33	0.32	0.31	0.35
Literate	0.30	0.27	0.30	0.32	0.30	0.30	0.30	0.29	0.29	0.30	0.27	0.29
Primary school	0.21	0.18	0.18	0.20	0.18	0.18	0.19	0.18	0.17	0.17	0.15	0.18
Secondary school	0.12	0.11	0.10	0.11	0.11	0.12	0.13	0.12	0.10	0.12	0.12	0.12
High school	0.07	0.07	0.06	0.06	0.05	0.08	0.08	0.09	0.09	0.07	0.08	0.08
Technical high school	0.05	0.05	0.05	0.04	0.04	0.05	0.04	0.05	0.05	0.05	0.06	0.05
University	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Employment												
Non-agricultural	0.16	0.14	0.14	0.14	0.13	0.14	0.14	0.14	0.13	0.13	0.13	0.14
Agricultural	0.28	0.25	0.26	0.31	0.28	0.25	0.27	0.24	0.23	0.23	0.17	0.25
Country average												
	0.19	0.16	0.17	0.17	0.17	0.16	0.16	0.15	0.15	0.15	0.14	0.15

Source: Calculated from the micro data set by Turkish Statistical Institute's (TUİK), income and living conditions research.

Table 4 - Multidimensional poverty values in Turkey.

Variable / Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*Average MPI*
Region												
Istanbul	0.38	0.37	0.37	0.38	0.37	0.38	0.36	0.36	0.34	0.36	0.33	0.36
Western Marmara	0.42	0.42	0.42	0.40	0.39	0.39	0.39	0.38	0.36	0.37	0.33	0.38
Aegean	0.43	0.42	0.40	0.39	0.37	0.38	0.37	0.36	0.35	0.37	0.34	0.37
Eastern Marmara	0.41	0.39	0.39	0.40	0.39	0.40	0.39	0.38	0.36	0.36	0.34	0.38
Western Anatolia	0.40	0.40	0.39	0.40	0.38	0.38	0.36	0.36	0.35	0.34	0.34	0.37
Mediterranean	0.46	0.45	0.43	0.42	0.42	0.42	0.42	0.41	0.40	0.40	0.39	0.41
Central Anatolia	0.47	0.46	0.47	0.46	0.45	0.44	0.43	0.43	0.40	0.39	0.39	0.43
Western Black Sea	0.46	0.44	0.46	0.44	0.45	0.43	0.42	0.42	0.40	0.40	0.39	0.42
Eastern Black Sea	0.46	0.45	0.44	0.44	0.44	0.47	0.46	0.44	0.42	0.40	0.40	0.44
Northeastern Anatolia	0.55	0.51	0.53	0.53	0.52	0.52	0.52	0.53	0.50	0.48	0.47	0.51
Eastern Anatolia	0.56	0.55	0.53	0.54	0.51	0.52	0.51	0.49	0.47	0.48	0.44	0.50
Southeastern Anatolia	0.58	0.58	0.55	0.55	0.54	0.52	0.52	0.53	0.49	0.47	0.45	0.51
Household size												
1	0.37	0.38	0.36	0.37	0.36	0.36	0.35	0.35	0.33	0.33	0.32	0.34
2	0.42	0.41	0.40	0.39	0.38	0.38	0.37	0.37	0.35	0.35	0.33	0.37
3-5	0.50	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.46	0.45	0.43	0.47
5+	0.62	0.59	0.61	0.61	0.62	0.62	0.61	0.60	0.58	0.57	0.56	0.60
Educational level of household head												
Illiterate	0.60	0.60	0.59	0.59	0.57	0.58	0.56	0.56	0.54	0.54	0.53	0.56
Literate	0.55	0.53	0.54	0.54	0.52	0.52	0.51	0.51	0.49	0.48	0.47	0.51
Primary school	0.48	0.47	0.46	0.46	0.46	0.46	0.45	0.45	0.43	0.43	0.41	0.45
Secondary school	0.42	0.41	0.42	0.41	0.40	0.41	0.40	0.40	0.38	0.38	0.37	0.39
High school	0.36	0.35	0.35	0.36	0.35	0.36	0.36	0.35	0.34	0.34	0.32	0.35
Technical high school	0.36	0.35	0.34	0.34	0.34	0.35	0.34	0.34	0.33	0.33	0.31	0.33
University	0.29	0.28	0.28	0.27	0.27	0.27	0.27	0.26	0.25	0.25	0.24	0.26
Employment												
Non-agricultural	0.44	0.42	0.42	0.42	0.41	0.41	0.40	0.40	0.38	0.38	0.36	0.40
Agricultural	0.54	0.52	0.53	0.52	0.51	0.52	0.51	0.52	0.50	0.49	0.48	0.51
Country average												
	0.46	0.44	0.44	0.44	0.43	0.43	0.42	0.42	0.40	0.40	0.38	0.41

Source: Calculated from the micro data set by

erty values were almost zero (0.01) according to the one-dimensional poverty approach, while the same varied between 0.24 and 0.29 in the multidimensional approach.

The values calculated through both methods were also similar under the employment variable. For the year 2016, the poverty value was 0.13 for households employed in the agricultural industry and 0.17 for households employed in other industries according to the one-dimensional poverty approach. On the other hand, while the change in the employment-based values calculated through the two methods was in parallel, the values calculated through the multidimensional approach were seen to be higher (0.36 and 0.48 respectively).

4.2. *Impact of social expenditures*

The results of the analysis carried out on the variables thought to be effective on the multidimensional poverty of households are presented in Table 5. While equation number 1 presents the results of the OLS model, equations number 2, 3, 4, and 5 present the results of the 3SLS model. Equation number 2 contains the coefficients of the variables affecting household income without social expenditures. Equation number 3 contains the coefficients of the variables affecting the government social expenditures received by households, while equation number 4 contains the coefficients of the variables affecting the non-government social expenditures received by households. Equation number 5 contains the coefficients of the variables affecting the multidimensional poverty values of households based on the 3SLS model.

The Breusch and Pagan (1980) test was also implemented for the analysis (Lagrange Multiplier). The results of the test suggested the rejection of the H_o hypothesis (null hypothesis), which directed the analysis to the 3SLS technique. The Wu-Hausman test was also implemented for the analysis, the results of which suggested the rejection of the hypothesis that the government and private social expenditures received by households and household income without social expenditures were external to the multidimensional poverty of households. However, in equation number 4 for private social expenditures, the government social expenditures and household income without social expenditures variables were found to be statistically insignificant.

According to the results of the analysis, in the OLS model, private social expenditures and household income without social expenditures have a negative and statistically significant impact on multidimensional poverty. On the other hand, government social expenditures received by households have a positive and statistically significant impact on multidimensional poverty. Similarly, household size, age of the household head, square of the age of the household head, and occupation have a positive and statistically significant impact on multidimensional poverty. However, household size has a negative and statistically significant impact.

The 3SLS model provided similar results to the OLS model. This model also suggested that private social expenditures and household income without social expenditures have a negative and statistically significant impact, while government social expenditures received by households have a positive and statistically significant impact on multidimensional poverty. For other variables, household size, age of the household head, square of the age of the household head, and occupation have a positive and statistically significant impact on multidimensional poverty, while household size has a negative and statistically significant impact.

Robustness tests were implemented to analyze the sensitivity of the 3SLS model to different model specifications (Appendix). Firstly, it was taken into the consideration that the 3SLS model was probably not nonlinear. For this reason, square of the household size and square of the age of the household head were removed from the model. Secondly, the region variable was removed from the model and thirdly the year variable was removed. Then, it was thought that the extreme values in the data set might have affected the model. Thus, the lowest and highest 1st percentile of the income variable was removed in the fourth step, after which the lowest and highest 5th percentile was removed in the fifth step. In the sixth and last step, the effects of the economies of scale were considered. Household

Table 5 - The analysis of the factors affecting multidimensional poverty.

Variables	*OLS*	*3SLS*			
	MPI	*Income w/o social expenditures*	*Government social expenditures*	*Private social expenditures*	*MPI*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
MPI			2.0297*** (0.0432)	-5.8990*** (0.4956)	
Income w/o social expenditures	-0.0016*** (0.0000)		0.0022*** (0.0002)	-0.0160*** (0.0014)	-0.0016*** (0.0001)
Government social expenditures	0.0226*** (0.0004)			2.2020*** (0.1749)	0.4305*** (0.0059)
Private social expenditures	-0.0008*** (0.0001)				-0.0251*** (0.0006)
Household size	0.0781*** (0.0008)	9.2748*** (0.1766)	-0.1763*** (0.0066)	-0.1650*** (0.0542)	0.0741*** (0.0018)
Household size^2	-0.0046*** (0.0001)	-0.5709*** (0.0225)	0.0152*** (0.0007)	0.0233*** (0.0046)	-0.0059*** (0.0002)
Age	0.0038*** (0.0001)	1.1703*** (0.0285)	-0.0068*** (0.0008)	-0.0556*** (0.0043)	0.0020*** (0.0003)
Age^2	0.0000*** (0.0000)	-0.0092*** (0.0003)	0.0000 (0.0000)	0.0006*** (0.0000)	0.0000* (0.0000)
Occupation	0.0523*** (0.0009)	-0.8029*** (0.1920)	-0.0721*** (0.0055)	0.1108*** (0.0284)	0.0313*** (0.0019)
Asset tax			-0.0174*** (0.0019)		
Student dummy				0.4101*** (0.0234)	
Constant	0.1157*** (0.0034)	-21.0028*** (0.7546)	-0.0851*** (0.0208)	5.0334*** (0.0956)	0.1645*** (0.0076)
Education control	NO	YES	NO	NO	NO
Region control	YES	YES	YES	YES	YES
Year control	YES	YES	YES	YES	YES

Note: Total number of observations used in all equations was 177.162. While equation number 1 presents the results of the least squares model, equations number 2, 3, 4, and 5 present the results of the three-stage least squares model. All models included year and region dummies. The education control, showing the educational level of the household head, was included in equation number 2 only. The main variable here is the fact that educational level is taken into consideration in the calculation of MPI. In this way, education is included as a dependent variable among MPI variables. The values given in parenthesis are standard error values, while the asterisks show the levels of statistical significance. Here, one asterisk means a significance level of 10%, while two and three asterisks mean a significance level of 5% and %1 respectively.

income values were transformed into household equivalent income by use of the OECD equivalence scale. When the result is compared with equation number 5 in Table 5 for all model specifications, any significant change was not observed, which suggested that the analysis was robust against different model specifications.

In the study, the elasticity coefficient for income, government social expenditures and private social expenditures were also calculated in the OLS and 3SLS models (Table 6). The elasticity values of the income variable in the OLS and 3SLS models were found to be -0.1316 and -0.1276 respectively. The elasticity values of the government social expenditures variable in the OLS and 3SLS models were 0.0101 and 0.1923 respectively, while the elasticity values of the private social expenditures variable in the OLS and

Table 6 - MPI elasticity coefficient for the income, government expenditures and private expenditures.

	OLS	*3SLS*
Income w/o social expenditures	-0.1316***	-0.1276***
	(0.0008)	(0.0048)
Government social expenditures	0.0101***	0.1923***
	(0.0002)	(0.0026)
Private social expenditures	-0.0017***	-0.0526***
	(0.0002)	(0.0013)

Note: Elasticity coefficients were calculated based on the average values. The values given in parenthesis are standard error values that were calculated with the delta method. The asterisks show the levels of statistical significance. Here, one asterisk means a significance level of 10%, while two and three asterisks mean a significance level of 5% and %1 respectively.

3SLS models were 0.0017 and 0.0526 respectively. Elasticity values for the government and private social expenditures variables are thought to have increased significantly, considering the problem of endogeneity.

In both the OLS and 3SLS models, government social expenditures received by households were found to have a positive and statistically significant impact on multidimensional poverty, which is discussed in the following section of the study.

5. Discussion

One of the main arguments of the multidimensional approach in measuring poverty is that poverty measurement approaches based on income or expenditures (one-dimensional approach) cannot be sufficient to comprehend poverty. However, this does not mean that the effect of income or expenditures is completely ignored in the multidimensional measurement of poverty. Some of the indicators selected for multidimensional poverty measurement are directly affected by household income. For this reason, household incomes are also included in the analysis of factors affecting multidimensional poverty in Turkey. As expected, it was concluded that multidimensional poverty decreases as household income increases. However, in both methods, the effect of household income in reducing multidimensional poverty seems to be quite limited (elasticity values were about -0.13 in both methods).

In order to reveal the impacts of social expenditures on multidimensional poverty in Turkey, the social expenditures received by households were analyzed under two groups government and private expenditures, in parallel with various examples in the literature (Van den Berg and Cuong, 2011; Mitrut and Wolff, 2011; Salmon, 2008). As a result of the analysis, it was calculated that private social expenditures reduce multidimensional poverty, while government social expenditures increase it.

The literature provides examples that suggest the negative impacts of social expenditures can occur on poverty. As a result of their research in Vietnam, Van den Berg and Cuong (2011) stated that social expenditures can have a negative impact on poverty due to various reasons (dependence on social expenditures, getting used to laziness, reduced investments due to the burden on the government budget, etc.). van de Walle (2004), on the other hand, put forward those government social expenditures might "miss" the poor and that they might be less successful than private social expenditures in reaching those in real need for various political or bureaucratic reasons. Our analysis indicates that rural poverty is significantly more prevalent than in other regions. In addition, Impiglia and Lewis (2019) emphasize the critical role of social protection mechanisms in alleviating rural poverty. It is therefore important to consider the possibility that government support may "miss" the issue of rural poverty and take appropriate measures to address this challenge. In addition to these researches, there are studies showing that there may be a "crowd-out" effect between government and private social expenditures. As a result of a research conducted in the United States, Payne (1998) found that government and private social expenditures can be alternatives to each other and that by choosing one of them, households can cause a negative effect on the other in the medium or long term. In addition, this problem, revealed as a result of the analyses of government social expenditures, might be resulting from the rate of informal employment. When it is considered that government social expenditures can reach formally employed persons easier compared to informally employed persons, government social expenditures may become less effective in countries such as Turkey where the

rate of households with at least 1 informal worker is around 37%.

In Turkey, there have been studies analyzing the effects of social support expenditures based on a one-dimensional poverty approach. These studies suggest that social support programs are effective tools for reducing poverty. For instance, Ertekin and Hayat (2022) calculated the impact coefficient of social support on poverty reduction to be approximately 0.20. Sarisoy and Koç (2010) calculated different coefficients for different social groups and concluded that social support programs reduce poverty across all groups. However, our study indicates that when taking a multidimensional approach to poverty, significantly different results are obtained compared to the existing literature. In fact, the effectiveness of state social support programs in reducing poverty is even a subject of debate.

The impacts of private social expenditures on multidimensional poverty were found to be significant and negative in both approaches, which is well in line with the literature and economic theory. However, the coefficients of private social expenditures, thus their impact on multidimensional poverty, were found to be quite low. This may be due to the fact that social expenditures are risky in terms of sustainability accessibility and that they are, due to their nature, far from considering poverty as a structural problem.

6. Conclusion

In this study, the multidimensional poverty approach was adapted to Turkey, MPI values were calculated for a period of 11 years through this approach, and these values were compared with the one-dimensional poverty values. As a result of these calculations and comparisons, it was found that MPI values are approximately 2.5 times higher than OPI values in Turkey (11-year average MPI is 0.41 while OPI is 0.15) and there are significant differences between OPI and MPI values in certain regions of Turkey (up to 3 times). Especially for families employed in the agricultural industry, a 3-fold difference was calculated between the MPI and OPI values. This makes the adequacy of OPI, a poverty measurement method, questionable in understanding the poverty level of households employed in the agricultural industry. We conclude that alternative measures of poverty, such as the Multidimensional Poverty Index, could help improve the understanding of rural people's poverty.

Under the study, the impacts of the social expenditure system used in reducing poverty on multidimensional poverty were also analyzed. The analysis was carried out with 2 different econometric methods (OLS and 3SLS). In both econometric approaches, the results of the analysis revealed that private social expenditures received by households and household income without social expenditures have a negative impact on their multidimensional poverty, while government social expenditures have a positive effect. This suggests that the government social expenditure system in Turkey is inefficient and that the benefits it provides are quite limited.

We think that further research should focus on the impacts of specific government social expenditure policies on multidimensional poverty. In this way, more in-depth information can be provided for policymakers. We hope that this will be beneficial for policymakers in establishing and implementing sustainable development goals in developing countries such as Turkey.

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Appendix

Table A.1 - Robustness checks.

VARIABLES	*(1) Nonlinearity*	*(2) Without region*	*(3) Without year*	*(4) Dropping 1st percentile*	*(5) Dropping 5th percentile*	*(6) Per-adult estimates*
Income w/o social expenditures	-0.0019***	-0.0017***	-0.0016***	-0.0020***	-0.0021***	-0.0023***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Government social expenditures	0.3745***	0.3953***	0.4457***	0.4090***	0.4147***	1.0544***
	(0.0056)	(0.0051)	(0.0062)	(0.0067)	(0.0092)	(0.0136)
Private social expenditures	-0.0217***	-0.0254***	-0.0284***	-0.0305***	-0.0417***	-0.0563***
	(0.0005)	(0.0006)	(0.0007)	(0.0009)	(0.0012)	(0.0008)
Household size	0.0345***	0.0726***	0.0734***	0.0725***	0.0711***	0.0601***
	(0.0006)	(0.0018)	(0.0019)	(0.0019)	(0.0021)	(0.0020)
Household size²		-0.0059***	-0.0058***	-0.0056***	-0.0058***	-0.0032***
		(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Age	0.0024***	0.0026***	0.0016***	0.0026***	0.0023***	0.0013***
	(0.0000)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Age²		0.0000	0.0000***	-0.0000	0.0000	0.0000**
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Occupation	0.0335***	0.0282***	0.0327***	0.0291***	0.0247***	0.0427***
	(0.0017)	(0.0018)	(0.0019)	(0.0019)	(0.0020)	(0.0020)
Constant	0.2332***	0.1397***	0.1901***	0.1718***	0.1937***	0.1954***
	(0.0040)	(0.0070)	(0.0077)	(0.0078)	(0.0087)	(0.0083)
Region control	YES	NO	YES	YES	YES	YES
Year control	YES	YES	NO	YES	YES	YES
Observations	177,162	177,162	177,162	173,616	159,446	177,162

Note: These calculations present the results of the three-stage model equation whose dependent variable is MPI. The 1st model was created through the removal of nonlinear household² and age² variables. In the 2nd and 3d models, region and year dummies were removed respectively. In the 4th equation, the 1st and 99th percentiles of income were removed from the data set, while the 1st and 95th percentiles were removed. In the 6th equation, the analysis was made based on per-adult values by dividing the income and expenditures variables by the equivalence scale. The values given in parenthesis are standard error values. The asterisks show the levels of statistical significance. Here, one asterisk means a significance level of 10%, while two and three asterisks mean a significance level of 5% and %1 respectively.

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