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Measuring the economic sustainability of Italian farms using FADN data

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Abstract: In recent literature, the issue of sustainability and its measure has been addressed with different approaches that depend on the multidimensional nature of the concept and the specific sector and context to which it applies. The present work focuses on the economic sustainability component and suggests an operative measure at the farm level. The measure of economic sustainability has been applied to Italian family farms using Farm Accountancy Data Network (FADN). Based on this data, an efficiency indicator (*EI*) and two income indicators [a factor profitability indicator (*FPI*) and a comparable income indicator (*CII*)] expressing the ability to remunerate the entrepreneur's production factors at their opportunity cost and the farm's income capacity have been used in a principal component analysis (PCA) to build an economic sustainability index (*SI*). The index was used to describe Italian farms' economic sustainability levels but was also the cue to discuss problems related to identifying economic sustainability thresholds and the trade-off between efficiency and income components.

Keywords: efficiency; Farm Accountancy Data Network; farm income; farm viability; statistical indicator

Since the publication of the Brundtland Commission report, sustainability has become increasingly relevant for the agricultural sector. More than 30 years later, the 2030 Agenda for Sustainable Development and the 17 Sustainable Development Goals (SDGs) place sustainability at the centre of the global political agenda, recognising the central role of the food system, and agriculture in particular, in achieving a higher level of prosperity for people and the planet, now and in the future. Among the 17 goals, the second, titled Zero Hunger, explicitly refers to the promotion of sustainable agriculture as a key element in achieving food security and improving nutrition (Gil et al.2019). In line with the SDGs, the EU Green Deal and the Farm to Fork Strategy launched by the European Commission, aim to promote a more sustainable food system. The Farm to Fork Strategy is the basis for a new legislative framework to facilitate the transition to sustainability in EU agri-food systems over the next 15 years (Baldock and Hart 2021).

The multidimensional nature of the sustainability concept, based on the economic, social, and environmental components, caused this issue to be tackled by very different approaches that enhanced the debate concerning the meaning of sustainable development but at the same time suffered from a lack of a punctual systematisation (Copus and Crobtree 1996; Hansen 1996; Reig-Martínez et al. 2011). That is particularly true in studies concerning the search for methodologies and indicators to assess the level of sustainability.

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These studies vary according to several factors (Binder et al. 2010; van Passel and Meul 2012): the assessment objectives, how sustainability is defined, the relative importance given to its three components, and the scale to which the analysis refers, i.e. the farm level rather than at production system, landscape, or region level (Reig-Martínez et al. 2011). These factors influence the selection of measuring criteria and related indicators, but the assessment also depends on operative choices such as the aggregation and interaction procedures (Binder et al. 2010; van Passel and Meul 2012; Chopin et al. 2021).

There is no doubt that, from an operational point of view, a shared measure of sustainability is needed, allowing for the assessment of the extent to which a production system is sustainable and the effects an intervention can have on sustainability (Farrell and Hart 1998). As stated by Rigby et al. (2001), the operationalisation via indicators of the sustainability concept is useful even without a clear and objective definition of the concept itself because it helps 'to promote and develop the discussion of sustainable agriculture in a more practically-orientated manner'. Moreover, building indicators make explicit the relative importance given to different aspects of sustainability, highlight an approach's strengths and weakness, and feed the debate on aspects that should be further explored (Rigby et al. 2001).

While the systemic nature of sustainability requires that all its components should be integrated into the assessment process, indicators of each dimension should be fully explored and identified before proposing any composite index (Callens and Tyteca 1999; van Passel et al. 2007). This work attempts to contribute toward this direction and focuses on the economic dimension of sustainability at the farm level. It proposes a synthetic indicator that can measure the farm's economic sustainability and allows for comparing the viability levels of farms and production systems. Such an indicator could help define reference levels and identify needs and targets for policy intervention. Moreover, it could be the starting point for examining synergies and trade-offs among the three dimensions of sustainability and analysing the impacts of different policies.

In this work, the measure of economic sustainability has been applied to Italian family farms using Farm Accountancy Data Network (FADN) data. Data availability is a relevant characteristic for indicator selection and assessment procedures, and the use of the FADN database guarantees homogeneous information over time and across farms. Moreover, FADN provides data on production practices and inputs that may be helpful for further integration of economic and environmental dimensions of sustainability (Zahm et al. 2008).

Measuring the economic sustainability. Several studies tried operationalising the concept of sustainability to compare production systems and support policies in the agricultural sector. The proposed indicators, quantification procedures, and assessment tools mainly reflect the different approaches to sustainability, the context of the study, and the spatial scale at which the indicators are used, besides the specific goals of the research (Hansen 1996; Binder et al. 2010; Chopin et al. 2021). Some studies aim to establish a common framework for the development or selection of indicators and can either use a goal-focused approach or refer to an approach based on key sustainability properties (van Cauwenbergh et al. 2007; Zahm et al. 2008; OECD 2013; FAO 2016). These frameworks may differ in terms of suggested themes, sub-themes, and indicators (de Olde et al. 2016; Arulnathan et al. 2020), as well as the aggregation and integration procedures they propose (Zahm et al. 2008). They help compare the impacts on each domain and consider trade-offs and synergies across the impact categories but can broadly differ in measurement models and score systems and therefore lack external comparability (Arulnathan et al. 2020). As a fact, evaluation tools with the same objective or level of analysis often use different indicators, nor are the criteria to select indicators the same (de Olde et al. 2016). For example, Nadaraja et al. (2021), in reviewing 40 articles using sustainability indicators in plantation agriculture, identified 143 indicators under the environmental dimension and a total of 90 and 60 under the social and economic dimensions, respectively. Some of them are differently termed but can refer to a single indicator, and for the same theme, different indicators are suggested (Nadaraja et al. 2021). Redundant and highly correlated indicators are often used (Gaviglio et al. 2017), and sometimes state and pressure indicators characterise sustainability components, thus mixing system-describing and goal-prescribing approaches.

From an economic perspective, sustainability refers to the efficient use of resources, competitiveness, and viability of the sector (Dillon et al. 2007; Spicka et al. 2019). Table 1 illustrates how some previous studies measured these concepts. O'Donoghue et al. (2016) underline that farm viability definitions vary according to the relevance given to the ability of the farm to meet the family income needs or remunerate family factors. Consequently, its measurement has been based on the

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Table 1. Economic sustainability issues and indicators used in previous studies

Reference	Economic sustainability issue	Indicators
Frawley and Commins 1996; Hennessy et al. 2008	viability	family farm income compared to the average agricultural wage, return on non-land assets
Vrolijk et al. 2010	viability	farm income, cash flow sign, rewards for the farmers input of labor and capital compared to the opportunity cost
Ryan et al. 2016	productivity	gross output/utilised agricultural area
	profitability	income per unpaid labor unit, market-based gross margin (less subsidies) per hectare
	markey orientation	proportion of output derived from the market
	viability	capacity to remunerate family labor on the farm at the average agricultural wage and the capacity to provide an additional 5% return on non-land assets (Frawley and Commins 1996)
Latruffe et al. 2016	productivity	total farm output in value related to UAA, total farm output in value related to the number of LU, total farm output in value related to total assets in value, total farm output in value related to total farm labor
	profitability	farm NVA related to UAA, farm NVA related to the number of LU, farm NVA related to total assets in value, farm NVA related to total farm labor
	viability	farm income related to family labor
Zahm et al. 2008	economic viability	available income per worker compared with the national legal minimum wage, economic specialisation rate
	independence	financial autonomy, reliance on direct subsidies from CAP and indirect economic impact of milk and sugar quotas
	transferability	total assets minus lands value on non-salaried worker units
	efficiency	operating expenses as a proportion of total production value
de Otálora et al. 2021	profitability	net farm income, land productivity, animal productivity, feed efficiency
	autonomy	economic self-sufficiency, feed self-sufficiency
	farm diversification	food production, economic diversification, non-food earnings, added value products
	durability	succession and transferability
Gaviglio et al. 2017	economic viability	value of production/utilised agricultural area, added value/agricultural working units
	persistence	farm ability to generate income given by EBITDA/value of production, ratio of (EBITDA + CAP subsidies) and family working units
	independence	CAP independence given by public subsidies/farm income, autonomy measured by total amount of contracted loans
	diversification	diversification of production given by the number and relative importance of products and services sold by the farm, business diversification
	multifunctionality	economic weight of non-agricultural products and services

UAA – utilised agricultural area; LU – livestock units; NVA – net value added; CAP – Common Agricultural Policy; EBITDA – earnings before interest, taxes, depreciation and amortisation

ratio between farm net income (*FNI*) and a reference net income (*RNI*)/comparable income, and/or the capacity to guarantee rewards for the farmer's capital (Frawley and Commins 1996; Hennessy et al. 2008; Vrolijk et al. 2010; Spicka et al. 2019). Ryan et al. (2016) state that farm-level measures of sustainability capture the broad concepts of factors' productivity, profitability, market orientation and viability. Within the FLINT (Farm Level Indicators for New Topics in policy evaluation) project, Latruffe et al. (2016) select 10 economic

https://doi.org/10.17221/169/2022-AGRICECON

sustainability indicators related to productivity, profitability, and viability issues.

Zahm et al. (2008), in implementing the IDEA (Indicateurs de Durabilité des Exploitations Agricoles or Farm Sustainability Indicators) method, associate three other criteria to the economic viability: economic independence in relation to the capacity to invest, transferability and ability to carry on from one generation to the next, and efficiency of the production system, that is the capacity to make optimal use of resources.

In evaluating sustainability modelling approaches for dairy production systems, de Otálora et al. (2021) list 11 economic indicators of sustainability grouped into four categories: profitability, autonomy, farm diversification, and durability. Gaviglio et al. (2017) systematise indicators from a literature review and identify five groups representing economic viability, persistence, independence, diversification and multifunctionality.

Therefore, despite a consensus on the economic sustainability concept, many differences exist in the operative approaches, and scholars have not yet decided upon an agreed measure. In a system-describing approach, such a measure should aim at accounting for the sustainability state and, when applied at the farm level, should allow for comparing farms across time and space and analysing how different techniques or policies impact the level of economic sustainability. Not all indicators listed in Table 1 seem to fulfil this objective. For example, diversification can be related to management strategies to reduce production risk, increase the farm's income stability, and improve economic sustainability. Then, diversification contributes to obtaining the farm's sustainability but should not be considered a measure of its level. The same is true for multifunctionality. It includes on-farm activities that broaden the range of products and services the farm supplies, enlarge the farm's flow of income and represent a strategic response to agricultural income problems (van der Ploeg and Roep 2003). Furthermore, economic viability can be considered a pre-condition for issues such as persistence or transferability that some authors propose to assess economic sustainability.

Some scholars underlined that sustainability indicators should meet some essential criteria. Among them:

i) Representing the state of the system. It should be possible to define which conditions the system has to fulfil to be sustainable. That implies the identification of some target, thresholds or minimum/maximum values (van Cauwenbergh et al. 2007; van Passel and Meul 2012).

ii) Providing information on how the system answers to sustainability-oriented policies. Knowing which factors influence sustainability, the indicator must be able to measure how the system reacts to changes in these factors (Callens and Tyteca 1999).

According to Hansen (1996), a valuable approach to characterise sustainability of agricultural systems should reflect the literal interpretation of sustainability as the 'ability to continue', represent an objective property of a system and treat sustainability as a quantitative characteristic. Moreover, a sustainability indicator should be: predictive, as sustainability deals with the future, stochastic, as the probability should be included in the sustainability measure, and diagnostic, because a comprehensive measure of sustainability should allow for analysing the effects of its determinants (Hansen 1996).

Taking previous studies into account, in this work we propose a complex index of economic sustainability whose construction is based on three assumptions. Firstly, a farm is economically sustainable if it is efficient and competitive, as the competitive capacity is one of the key elements for permanence in the market in the medium-long term. Secondly, farm persistence also depends on the ability to remunerate the farmer's production factors at their opportunity cost. Lastly, a necessary condition for the farm to continue during time is its ability to guarantee an adequate income for the family. That is particularly appropriate for family farms and is very relevant in the Italian context, where family farms mainly characterise the agriculture organisation and structure. In our opinion, an indicator built on these three statements is an exhaustive measure of the farm's sustainability state.

MATERIAL AND METHODS

The analysis of economic sustainability was carried out on Italian farms that were part of the FADN sample from 2015 to 2017. The analysis covered only family farms and simple companies, and all farming systems except granivores have been considered. Granivores were excluded because of the specific nature of the production techniques, closer to industrial processes. A total of 5 982 farms were analysed. For these farms, balance sheet data and some structural data were considered. All data has been averaged over the 2015–2017 period.

Following the assumptions on the conditions that guarantee the farm's sustainability, three indicators were estimated:

https://doi.org/10.17221/169/2022-AGRICECON

i) an efficiency indicator (*EI*);
ii) an indicator of the ability of the farm to remunerate the entrepreneur's production factors at their opportunity cost [factor profitability indicator (*FPI*)];
iii) an indicator of the farm's income capacity [comparable income indicator (*CII*)].

To estimate the *EI* at the farm level, we used a data envelopment analysis (DEA) approach. DEA is a non-parametric mathematical programming method that allows construction of a production frontier based on a set of decision-making units (DMUs) so that the best-performing observations define the efficient frontier and all points lie on or below the production frontier (Coelli 1995). The *EI* ranges from 0 to 1, with higher scores associated with higher efficiency. Compared to parametric optimisation, this method has the advantage of removing assumptions on the functional form of the frontier and the error distribution. We used an output-oriented model under the constant return of scale, which maximises outputs without requiring more of the observed input values (Charnes et al. 1978). In estimating the *EI* with the DEA model, the value of farm revenues, net of EU aids, was the output. On the inputs side, the most common inputs used in previous works on farm efficiency analysis (Forleo et al. 2021) were considered: utilised agricultural area (UAA), labour units, intermediate costs and non-land assets. For the analysis, the package Rdea in R was used.

The *FPI* and *CII* are strongly interrelated but refer to different aspects that define the farm's viability and focus on the use of the household's resources or living standards (Loughrey et al. 2022).

The *FPI* assesses the ability of the farm to remunerate the entrepreneur's production factors at their opportunity cost. It accounts for the convenience of family resources to remain in the sector in the medium-long term. Based on a methodology developed within the framework of the Italian FADN, this indicator is estimated by the ratio between the *FNI* and *RNI*, where *RNI* is the sum of the opportunity costs of all the farmer's family factors. When the *FPI* is lower than 1 the farm cannot guarantee the opportunity cost remuneration to the family labour and invested assets. The opposite is true when the *FPI* is equal to or higher than 1.

The indicator of the farm's income capacity (*CII*) was estimated by comparing the *FNI* to the average income reported by Eurostat for Italy for a family with two children. Different average incomes were considered according to the family working units.

A better description of the indicators used is in the electronic supplementary material (ESM); for the ESM see the electronic version.

Table 2 reports descriptive statistics of *EI*, *FPI*, and *CII*. On average, *FPI* and *CII* exceed 1, but the median values show that 50% of farms do not guarantee comparable income and factors' remuneration. Indeed, the *FPI* and *CII* distributions are highly skewed, and the variability is large even within each farming system, mainly because of the different structural characteristics and production models. The average value of the *EI*, equal to 0.31, shows a generally low level of efficiency in the use of farms' resources, but this is dependent upon the farming system and reaches a value of 0.5 in horticulture.

To obtain a complex economic sustainability index (*SI*), the three indicators have been used in a principal component analysis (PCA) with SPSS 26. One component was extracted that explained 69.4% of the total variance [Kaiser-Meyer-Olkin (KMO) test = 0.665; Bartlett test = 5 302.494; significance = 0.000]. Correlation coefficients and parametric and non-parametric tests have been used to analyse how *FPI*, *CII* and *EI* interact and highlight whether some pattern characterises the level of farms' economic sustainability.

Table 2. Descriptive statistics of factor profitability indicator (*FPI*), comparable income indicator (*CII*), and efficiency indicator (*EI*) by farming system

Farming system	*FPI*			*CII*			*EI*		
	median	average	SD	median	average	SD	median	average	SD
Fieldcrops	0.65	1.02	1.28	0.66	1.42	4.00	0.24	0.27	0.14
Horticulture	0.84	1.33	1.53	0.77	1.75	3.61	0.45	0.50	0.21
Permanent crops	0.82	1.16	1.25	0.79	1.46	2.59	0.31	0.35	0.16
Grazing livestock	0.94	1.31	1.31	0.99	1.85	4.95	0.25	0.29	0.15
Mixed	0.61	0.86	1.04	0.56	1.02	1.93	0.26	0.27	0.13
Total sample	0.77	1.13	1.28	0.76	1.51	3.67	0.28	0.31	0.16

Source: Authors' elaboration on FADN data (CREA-PB 2017)

https://doi.org/10.17221/169/2022-AGRICECON

RESULTS AND DISCUSSION

The component obtained by applying PCA to indicators of efficiency, factors profitability, and income capacity can be used to assess Italian farms' sustainability levels and analyse how efficiency and income issues are related to each other in defining the overall economic sustainability.

The construct validation of the *SI* was tested by correlating it to indicators measuring the same concept or a theoretically related concept. Table 3 reports correlation coefficients between the *SI*, some indicators used in previous studies synthesised in Table 1, and other structural indicators. The sign of the coefficients is coherent with expectations: the *SI* is positively correlated to indicators of economic viability, persistence, and multifunctionality, and negatively to the relevance of subsidies on the farm income. A farm's economic sustainability is supposed to be related to structural factors, and then a sustainability measure should maintain this link and reflect how changes in structural conditions affect economic performance. Indeed, positive correlations exist with the farm size, the working units, the invested capital, and the ratio of these factors.

Table 3. Correlation between the sustainability index (*SI*) and viability and structural indicators

Indicator	Correlation coefficient
Economic viability	
Value of production/UAA	0.234**
Value added/annual working units	0.793**
Persistence	
Farm ability to generate income (EBITDA/value of the production)	0.195**
EBITDA + subsidies/family working units	0.766**
Independence	
Public subsidies/farm income	–0.026*
Multifunctionality	
Economic weight of non-agricultural products and services	0.042**
Working units	0.451**
Family working units	0.288**
UAA	0.362**
Irrigated area	0.453**
Irrigated area/UAA	0.240**
Fixed capital	0.334**
Capital/UAA	0.102**
Rented area on total UAA	0.063**
Percentage of complementary activities revenues	0.063**

*, **Significance < 0.05 and < 0.01, respectively; UAA – utilised agricultural area; EBITDA – earnings before interest, taxes, depreciation and amortisation

Source: Authors' elaboration on FADN data (CREA-PB 2017)

Component scores are standardised values with $\mu = 0$ and $\sigma^2 = 1$. Therefore, positive or negative values identify a farm's sustainability as higher or lower than the average. Only 36.8% of the sample shows a positive *SI*. Still, the economic performance statistically differs across farming systems, except for mixed and fieldcrops whose mean values are lower than the average and not significantly different across them (Tables 4, 5).

To implement a sustainability measure, we need to fix some reference values to assess whether a farm reaches economic sustainability in absolute terms. That is not an easy task, as the reference level can have several meanings and be related to a minimum, sufficient, or target value, and each can be argued. Here, we chose to refer to a minimum level criterion to provide insight into Italian farms' economic sustainability. However, while a minimum level of factors' remuneration and farm's income directly translates into assuming *FPI* = 1 and *CII* = 1, the choice of the *EI* threshold is more ambiguous. Table 6 shows how the *SI* varies according to the *EI* when both *FPI* and *CII* are at least equal to 1. The *SI* is higher than the average when the *EI* is above 0.3 and increases by 0.234 points as the *EI* increases by 0.1 points.

Figure 1 illustrates the relationship between the *SI* and the *EI*; red and green dots distinguish whether farms respect the minimum income criteria. This graph helps understand how the choice of a specific threshold relates to the economic sustainability concept.

At first glance, negative values of the *SI* also include farms with good performance in terms of income and factors profitability. Conversely, *SI* above the average and good performances in terms of efficiency can also

Table 4. Descriptive statistics of the sustainability index (*SI*) by farming system

Farming system	Average	SD
Fieldcrops	–0.140	0.997
Horticulture	0.512	1.162
Permanent crops	0.094	0.906
Grazing livestock	0.036	1.124
Mixed	–0.255	0.732

Kruskal-Wallis test = 335.215; significance = 0.000

Source: Authors' elaboration on FADN data (CREA-PB 2017)

https://doi.org/10.17221/169/2022-AGRICECON

Table 5. Post hoc comparison for the Kruskal-Wallis test on sustainability index (*SI*): pairwise comparison by farming systems

Farming systems	Kruskal-Wallis test	SE	Kruskal-Wallis standard	Significance	Modified significance[a]
Mixed-fieldcrops	200.498	76.526	2.62	0.009	0.088
Mixed-grazing livestock	583.189	77.391	7.536	< 0.001	0.000
Mixed-permanent crops	875.505	74.327	11.779	0.000	0.000
Mixed-horticulture	1 584.606	110.833	14.297	0.000	0.000
Fieldcrops-grazing livestock	–382.691	63.138	–6.061	< 0.001	0.000
Fieldcrops-permanent crops	–675.007	59.343	–11.375	0.000	0.000
Fieldcrops-horticulture	–1 384.109	101.396	–13.651	0.000	0.000
Grazing livestock-permanent crops	292.316	60.454	4.835	< 0.001	0.000
Grazing livestock-horticulture	1 001.417	102.05	9.813	0.000	0.000
Permanent crops-horticulture	709.101	99.746	7.109	< 0.001	0.000

[a]Significance level modified for the number of tests according to Bonferroni
Source: Authors' elaboration on FADN data (CREA-PB 2017)

characterise farms that do not meet the income criteria. This result confirms our hypothesis on the need to consider the three indicators to build a complex and exhaustive index. Moreover, Figure 1 helps highlight how a measure of sustainability should be assessed differently in the short and medium-long term. Suppose a minimum threshold of the *EI* is fixed at 0.33 (one-third of the maximum, very close to the average level). In that case, the reference *SI* that respects all the minimum criteria corresponds to 0.164 (the graph's horizontal dot line). This discriminant value distinguishes sustainable farms (above the dotted line) from unsustainable (under the dotted line) in the short term. The reference value of 0.164 has a strong discriminant power: 70% of farms under the reference value do not meet the income criteria; on the opposite, 88.6% of farms with *SI* equal to or higher than 0.164 can generate a comparable family income and remunerate the family factors at their opportunity costs. By fixing the threshold *SI* = 0.164, 1 808 farms (30% of the Italian sample) can be classified as sustainable, with significant differences across farming systems (*V*-Cramer = 0.173; significance < 0.001) (Figure 2).

Table 6. Sustainability index (*SI*) thresholds according to different values of efficiency indicator (*EI*) when *FPI* = 1 and *CII* = 1

EI	*SI*
0.3	–0.162
0.4	0.072
0.5	0.307
0.6	0.541
0.7	0.776
0.8	1.010
0.9	1.245
1.0	1.475

FPI – factor profitability indicator; *CII* – comparable income indicator
Source: Authors' elaboration on FADN data (CREA-PB 2017)

Due to the positive relationship between the three primary indicators, the likelihood of not meeting the income criteria decreases when the *EI* increases (Figure 1). Nevertheless, from a theoretical point of view, choosing a definite threshold value of *SI* implies accepting trade-offs between the three indicators and a compensatory effect among them. These trade-offs could not always be coherent with the concept of economic sustainability, at least in the medium-long term. Competitive farms that cannot guarantee a sufficient income to the family are not likely to persist in the sector, except if they have an ancillary function for the household income. The same is true when the farm generates a comparable income, but the production is inefficient and not competitive.

Therefore, in the medium-long term, the sustainability measure should consider a minimum *EI* beside the *SI* reference value. The vertical line in Figure 1 identifies the threshold of the *EI* = 0.33. Farms at the left of the vertical line are likely to exit the sector in the medium-long term, while at the right of the vertical line, they are fully sustainable (green points above the dotted line) or will persist only with an ancillary function (red

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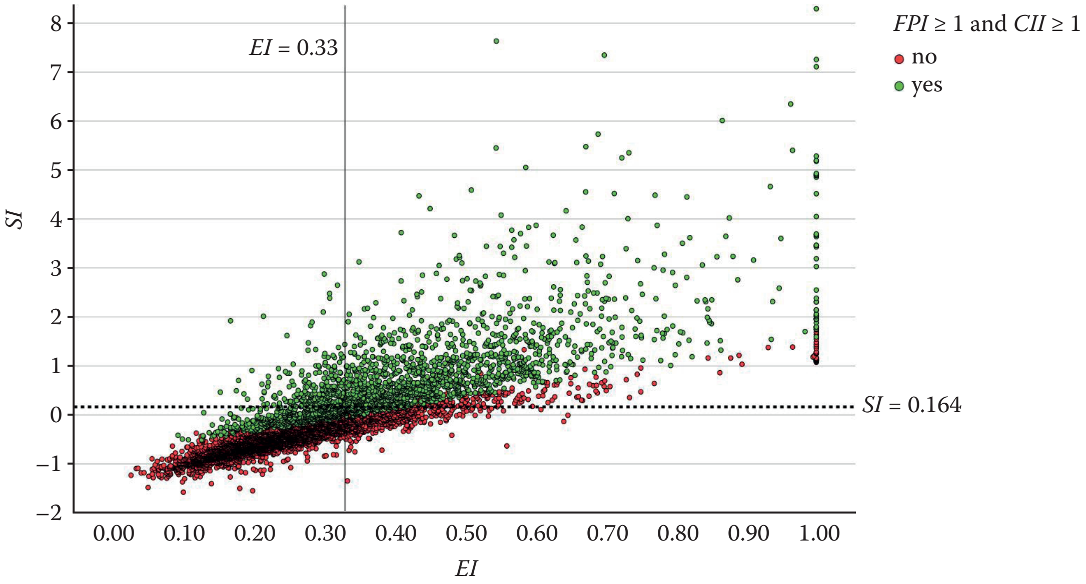

Figure 1. Farms by efficiency indicator (*EI*) and sustainability index (*SI*) according to the respect of minimum income criteria

FPI – factor profitability indicator; *CII* – comparable income indicator
Source: Authors' elaboration on FADN data (CREA-PB 2017)

points). Looking at both *SI* and *EI* thresholds, about 60% of Italian farms in the sample are likely to exit the sector because they are unsustainable in the short term and inefficient. A small component of sustainable but inefficient farms (269 units; 4.5% of the sample) is also at risk unless they undertake an innovation process. Conversely, 25.7% of the sample are both efficient and sustainable in the short term and represent a strong component of Italian agriculture. Nevertheless, some of them (206 out of 1 539) do not meet the income criteria and therefore will not persist unless external gainful activities supplement the farm income. The same is true for 10% of farms (efficient but unsustainable in the short term) whose persistence could depend on the specific role the farm plays in household income.

This picture is coherent with the findings of previous works both in Italy (Coppola et al. 2020) and in other EU countries (O'Donoghue et al. 2016). Nevertheless, a direct comparison is not possible. Indeed, as O'Donoghue et al. (2016) underline, levels and ranking of sustainability vary with the specific sustainability definition, estimation approach, that is opportunity cost or farm-level approaches, and assumptions on the average reference value.

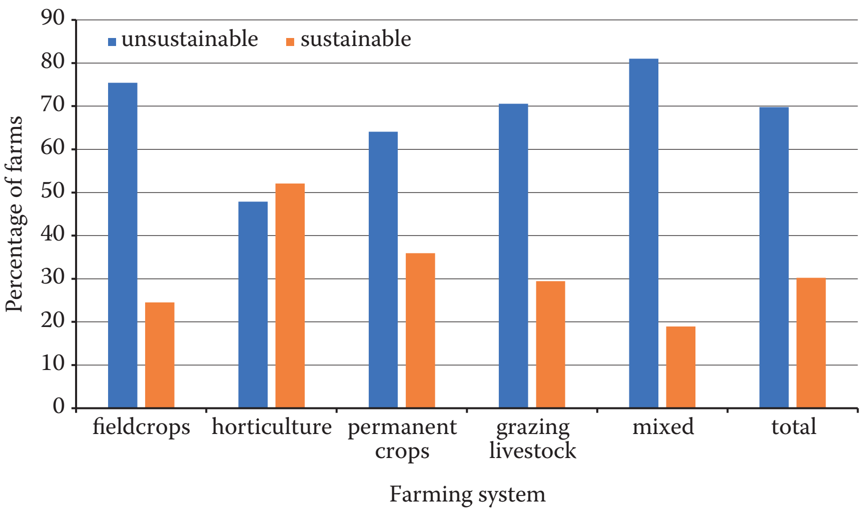

Figure 2. Percentage of sustainable/unsustainable farms by farming system when the Sustainability Index (*SI*) threshold is fixed at 0.164

Source: Authors' elaboration on FADN data (CREA-PB 2017)

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CONCLUSION

The work aimed to propose a measure of the economic sustainability of family farms. The proposed index allows for the ranking of farms according to their level of sustainability. The correlation of the index with structural variables and autonomy indicators represents a validation of the index and supports the possibility of using this measure to assess changes in the level of sustainability linked to structural interventions.

Some aspects characterise the present work with respect to previous studies. Firstly, the *SI* includes the *EI* besides income and factors' remuneration. Therefore, it differs from the farm's viability in Frawley and Commins (1996), Hennessy et al. (2008) and Vrolijk et al. (2010). This choice follows Hansen's (1996) definition of sustainability as the 'ability to continue', as efficiency is a key factor in ensuring the farm's competitiveness and persistence in the medium-long run.

Secondly, with respect to other studies listed in Table 1, the proposed *SI* aims to measure a state level and excludes strategies and factors that can affect the state (e.g. diversification, multifunctionality) or are effects of the sustainability level (e.g. durability, transferability). Then, the index is parsimonious and requires relatively limited data.

The empirical application to the Italian FADN sample highlighted the advantages and disadvantages of the proposed *SI*.

The use of PCA to obtain a synthetic index has some significant advantages. The aggregation of indicators through PCA is less subjective than other methods that often contain hidden assumptions and simplification (van Passel et al. 2007). Secondly, the obtained index (PCA scores) is continuous. It allows for ranking farms by the sustainability level and responds to marginal changes in primary indicators. Some drawbacks should be underlined, too. A first critical aspect emerging from the analysis concerns the definition of a threshold level that discriminates sustainable farms in absolute terms. Suppose the identification of the reference level assumes a minimum threshold criterion. In that case, the choice is quite simple as far as indicators linked to factor profitability and comparable income level are concerned, even if different comparable income levels could be chosen according to the living standards assumptions (Vrolijk et al. 2010; Spicka et al. 2019). More questionable is the choice of the efficiency level to consider. An average value could closely reflect the current production system but may overestimate the actual sustainability levels, especially when farming systems have higher efficiency values on average.

Secondly, the way the *SI* is built allows for a trade-off between the three primary indicators, and structural and production factors acting directly on the overall income can compensate for lower efficiency in resource use (and *vice versa*).

The trade-off between indicators opens a debate on whether sustainability thresholds should be identified differently in the short and medium-long term. Specifically, while in the short-term broader substitution between efficiency and income level can be admitted, in the medium-long term, the measure of sustainability should provide for a complementary relationship between indicators, and the threshold level of the *SI* should be subject to minimum values of all primary indicators.

The results of this study have several implications. From a research perspective, the findings of the work pave the way for the integration of economic issues with environmental and social sustainability. Nevertheless, there is a need to explore further the relationship between the primary economic indicators, the trade-off among them and how they affect sustainability in the short and the long term. A specific issue to face is related to the choice of the thresholds.

From a political point of view, a single index is easy to communicate to decision-makers (van Passel et al. 2007). It represents a useful tool for analysing and evaluating policy interventions.

Moreover, the findings of the work highlight the relevance of the efficiency issue and the role innovation and structural policies can play in guaranteeing farms' persistence. That confirms the right direction of the new agricultural policy where innovation and knowledge are considered transversal objectives for all interventions.

This study has some limitations. Firstly, analysed data refer to only one period. A comparison across time could give better insights into farms' sustainability patterns and help to understand the relationship between each primary indicator and the farm's sustainability evolution. Secondly, the analysis did not concern the factors that affect the primary indicators and, therefore, the *SI*. A study of these factors and how they act on the economic *SI* could be the base to define policy interventions and represent a future research direction.

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