NEW MEDIT

CIHEAM BARI

MEDITERRANEAN JOURNAL OF ECONOMICS, AGRICULTURE AND ENVIRONMENT

Poste Italiane Spa Spedizione in Abbonamento Postale Periodico ROC Centro Nord aut. N° 0029 - € 15,00.

1
QUARTERLY
VOL. XX - N. 1
MARCH
2021

Bononia University Press

ISSN: 1594-5685
www.newmedit.iamb.it

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Vol. XX - n. 1/2021

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http://www.newmedit.iamb.it

Publisher
Bononia University Press
Via U. Foscolo, 7
40123 Bologna (Italy)
tel.: +39 051 232882
fax: +39 051 221019
email: comunicazione@buponline.com

Subscription rate
Print: Italy: € 40; Foreign: € 90.

Subscription office
ordini@buponline.com

Abstract and Index citation
NEW MEDIT is indexed in: SCOPUS, EBSCO, ISI Web Science,
CAB Abstracts, EconLit, AGRIS/FAO database

Web page
http://www.newmedit.iamb.it

ISBN: 978-88-6923-768-3

ISSN: 1594-5685

ISSN online: 2611-1128

Graphic Layout
DoppioClickArt – San Lazzaro (BO)

Cover design
Debora Degl'Innocenti

Registrazione
Tribunale Ordinario di Bari, n. 1546 del 4/1/2002

Direttore Responsabile
Giulio Malorgio

NEW MEDIT è associato alla USPI

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Foreword

Osman et al. conduct a mixed multiplier analysis, under water and land constraints, to identify the seasonal agricultural activities in Egypt with high output and income multipliers. The results demonstrate the significance of addressing Nile water constraints not only for agriculture, but also for the overall economy. Policies that enhance water productivity, particularly in winter season, generate outstanding increases in output, income, and employment through sizable multiplier effects.

Mahdhi, *Dhehibi*, *Brokman and Chouikhi* measure the efficiency level of Water Users Associations (WUAs) in the coastal oases of Gabès (Southeastern Tunisia) and assessing its main determinants. A key finding of the study is that WUAs are clearly inefficient. The inefficiency found can be mainly attributed to the number of water pumping stations managed, the ratio of water losses and the WUAs' age. The results also show a discrepancy between the technical efficiency values calculated under the CRS and VRS assumptions, resulting in a 20% scale inefficiency.

Employee satisfaction has become a dominant managerial concern in business, because employees are increasingly important for organizational success, growth and competitiveness. The authors *Carpio and Urbano* analyse a survey data set of 381 observations in Spanish agribusiness firms of the agri-food value chain. The results show flexible remunerations of emotional salary are determinants of employee satisfaction. Whole-of-chain employees showed the greatest satisfaction with the use of social media in personnel management. This study contributes to the literature by investigating the effect of current social and digital business skills on employee satisfaction in the agri-food value chain.

Bojnec and Fertő investigate the drivers of farm size and farm size growth in Slovenia during the period 2007-2017 using a farm-level Farm Accountancy Data Network dataset within a quantile regression framework. The findings suggest that growth in farmland size is driven by initial farmland size and policy subsidy support. Contrary to expectations, human capital does not play an important role in either farmland size or farmland size growth according to quantile regressions.

Hayran et al. deals with a study concerning to the perceptions of the farmers in the Mersin province about the effects of climate change in agricultural system. Farmers primarily perceive climate change over production costs and the reduction in yield. Moreover, they are highly aware of its relation to natural events such as floods, drought, and storms. Nevertheless, inappropriate agricultural practices also lead to the negative consequences caused by climate change.

Benmehaia examines aggregate supply response of 19 selected crops in Algerian agriculture during the 1966-2018 period by employing cointegration analysis and Error Correction Model (ECM). Findings indicate that the long-run elasticities of all selected crops with respect to prices are statistically significant and mostly low, whereas short-run elasticities are lower, which appeals to the adequacy of adjustment to economic incentives. Furthermore, the results of the ECM confirmed the positive responsiveness to prices with differential rates of adjustment for selected crops, ruling out the applicability of a presumed perverse supply response in Algerian agriculture.

The authors *Perujo-Villanueva and Colombo* propose a methodology for calculating the real estate value of the land belonging to a farm, the latter being understood as the set of the parcels, not only on the basis of production factors such as surface area, type of crop and intensity, but also by including parameters relating to the fragmentation of the land. Fragmentation increases production costs and reduces farmers' incomes and by extension the real estate value of the farm. The results show that fragmentation of the land reduces its value by between 51% for a 10 ha farm and 12% for a 30 ha farm. The reorganization of the ownership system or the promotion of systems for the common management of land could increase the profitability and therefore the value of land according to the 'income capitalization' approach.

Cardone, *Bottalico and Prebibaj* consider the traditional organic olive farm as a case study for the assessment of economic sustainability not as well as a representative farm but in order to test a statistic approach. The methodological approach used is in line with the Sustainability Assessment of Food and Agriculture Systems (SAFA). In this overall frame, factors correlated to the production system and responsibility of farmers (e.g. decision what to produce, cropping practices, capital held, etc.) largely determine the economic sustainability of farm and, consequently, the sustainability of farm.

Bor and Tuncay investigate the price dynamics between retail milk price and raw milk price in the Turkish fluid milk market. The authors find that the transmission between the two prices has been asymmetric in both the long term and short term period. Differences between the farm milk prices and retail milk prices may exist due to marketing costs across the supply chain and pricing policies associated with the market structure. Results of the long-run analysis indicate a significant market power in the fluid milk market. Therefore, in this asymmetric case, the deviations are likely to be the reason for the market power of the processors/retailers and the reason for the oligopolistic market structure in the sector.

Can the Nile generate output, income, and employment in Egypt? A mixed multiplier analysis

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Alfredo Mainar-Causapé***, Sofía Jiménez Calvo****

DOI: 10.30682/nm2101a
JEL codes: D57, E24, O21, Q11, R11, R58

Abstract

Nile water availability is one of the major constraints for agricultural development in Egypt. This study conducts a mixed multiplier analysis, under water and land constraints, to identify the seasonal agricultural activities with high output and income multipliers. It uses a 2008/09 SAM for Egypt with a detailed representation of Nile-related production factors employed by agricultural activities across irrigation seasons. The results demonstrate the significance of addressing Nile water constraints, not only for agriculture, but also for the overall economy. Policies that enhance water productivity, particularly in the winter season, generate outstanding increases in output, income, and employment through sizable multiplier effects.

Keywords: *Water availability, Irrigation efficiency, Agricultural productivity, Mixed Multiplier Analysis, Egypt.*

1. Introduction

In 2019, the Egyptian economy grew by 5.6% compared to 4.5% in the preceding four years. Nevertheless, the long-standing issues of poverty, public deficit and unemployment seem to be unresolved; 32.5% of Egypt 99 million citizens are poor (CAPMAS, 2019) and 60% are classified as either poor or vulnerable. In addition, public deficit (accounting for 10% of GDP) and the double-digit unemployment rate of 11.3% poses serious challenges to an economy with one of the fastest growing populations in the world (2%) (WB, 2019).

Although the share of agriculture in GDP has been declining since 2000 (from 16% to 11% in 2018) and its share in employment decreased by almost 10 percentage points in the last twenty years (Zaki *et al.*, 2020), agriculture, forestry, and fishing remain a major sector in Egyptian economy. This labour-intensive sector absorbs 25% of the total employment and 36% of female employment in 2019. In addition, the agri-food sector is a key source of foreign currency, with food accounting for 16% of total exports (WB, 2019).

Egypt has been affected by serious issues of

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water scarcity and quality deterioration, which could be further exacerbated by climate change and increasing population growth. Agriculture and livestock in Egypt are highly dependent and constrained by the availability and quality of Nile water. Agricultural activities consume about 80% of the Nile water budget (Abdelhafez *et al.*, 2020). The Nile contributes to 83% of the water budget, followed by groundwater (11%), and non-conventional sources, i.e., recycled drainage water, treated sewage water, and desalinated seawater. Agricultural land is also constrained by the available water resources. Only 3.5% of Egypt's total land area is irrigated, 85% of which is located in the Nile Valley and Nile Delta. Besides, 35% of Egypt's agricultural land is affected by high salinity, especially in the (over-populated) Nile Delta, where 60% of cultivated land in the northern Delta is affected by salinity (ICARDA, 2011). Under these water scarcity conditions, Egypt follows a precise seasonal multi-cropping system in three irrigation seasons: winter (November-May), summer (May-September) and *Nili*, i.e., Nile floods (September to November). The main crops are wheat, berseem (an Egyptian clover used for fodder) and broad beans (in the winter season), cotton, sugar cane and rice (in the summer season), whereas maize and millet crops are cultivated in the flood season. The Egyptian seasonal irrigation system helps improve land productivity. For example, cultivating berseem in the winter improves the soil quality before the soil-demanding cotton is planted in the summer. Most crops are not region-specific, with the exceptions of sugar cane, which is mainly planted in the Nile Valley, and rice, which is planted in Nile Delta. Nile Delta, where 60% of Egypt's total population inhabits, accounts for more than 60% of the total irrigated land.

The development of the agricultural sector is threatened by water scarcity (Fuglie *et al.*, 2020). At the same time, Egypt's livestock sector production is declining because of many technical reasons, among which are the lack of fresh drinking water and groundwater contamination (Ahmed *et al.*, 2020). Under these circumstances, investments aiming at raising water and land productivity are crucial to guarantee a stable output increase.

Osman *et al.* (2016) argue that enhancing water productivity and irrigation efficiency could compensate for the shortage of water supply. Since water scarcity is the predominant issue, improving water quality is the only feasible way to enhance agricultural productivity and efficiency. Better water quality boosts income by 4% and induces increases in the production of high-value crops with a 64% increase in rice exports (Osman *et al.*, 2019).

The USAID Feed the Future Egypt Food Security and Agribusiness Support project (2015-2020) aims at enhancing food security, income, and employment by improving water and agriculture productivity. The project's impact assessment has two twin objectives, i.e., identifying the seasonal agricultural activities with the highest potential for generating output, income, and employment, as well as leveraging the linkages between agriculture and the rest of the economy.

It is in this context that this study addresses the intriguing policy question on whether the improvement of irrigation water and agriculture productivity could generate non-agricultural output, income, and employment. The study examines multiplier effects using a Social Accounting Matrix (SAM) mixed multiplier analysis that considers supply-side constraints in agriculture. A SAM provides a consistent framework to record expenditure and income flows in the economy. In this square matrix, each agent is represented by a column and a row, where expenditures and incomes are both recorded (Pyatt, 1988; Pyatt & Round, 1977).

While SAM multiplier analysis has long been employed for Egypt, few studies calculate output and income multipliers considering supply-side constraints, and no study focuses on multipliers for seasonal agricultural sectors to date. Ernst & Sarabia (2014) and (2015) calculate output and employment multipliers for the construction sector. Kamal (2018) identifies manufacturing and services with high output and employment multipliers. Moursi & Mossallamy (2010) use employment and output multipliers to estimate direct, indirect, and induced effects of Egypt's stimulus package 2008/09. Fayed & Ehab (2017) examine the supply chain and linkages of the construction sector.

This study fills this gap in the literature; it identifies the seasonal agricultural activities with high output, income and employment multipliers using a SAM for Egypt 2008/09 (Osman *et al.*, 2015b). The SAM introduces irrigation water as a distinct production factor. It provides a thorough representation of agricultural activities across irrigation seasons allowing specific supply constraints on seasonal agricultural activities. A mixed multiplier analysis under water constraint conditions assumes that agriculture output expands only with improvements in water productivity. The study simulates exogenous productivity shocks that generate increases in agricultural outputs. It measures the multiplier effects of these changes in agricultural outputs on non-agricultural output, household and government income as well as employment.

Improvements in water and agriculture productivity generate employment through direct and indirect effects. Induced employment injects (private) income into the circular flow of the economy through the consumption channel. The multiplier mechanism entails higher production, tax, and (public) income. However, for some sectors, increases in productivity and output in other sectors could generate unemployment. Therefore, it is important to unravel the sector-specific forward and backward linkages and induced employment and income effects in order to identify sectors with high multipliers. Indeed, omitting the inter-linkage between the seasonal agriculture sectors and the rest of the economy means underestimating the importance of agriculture in generating income and employment and misleading economic policy makers.

The rest of the paper is structured as follows. Section 2 describes Egypt SAM as a framework for the economy's circular flow. Section 3 introduces the employed mixed multiplier analysis. Section 4 discusses the results and Section 5 concludes the paper.

2. Circular flow in the Egyptian economy

2.1. *Social Accounting Matrix*

The analysis is conducted employing a SAM for Egypt 2008/09, which has the unique advantage of including detailed accounts for seasonal agricultural sectors (Osman *et al.*, 2015a; 2015b), including irrigation water as a separate production factor, and detailed data on areas of cultivated land and water used in irrigation. This SAM has 102 accounts: 54 activities, 16 commodities, 19 factors, 5 institutional accounts, 4 tax instruments as well as trade margin, savings/investment, rest of the world. In addition, the SAM is completed by physical employment data compiled in the form of an employment vector, (CAPMAS, 2010). Table 1 portrays the macro SAM for Egypt 2008/09.[1]

In general, a SAM provides an appropriate methodology to measure generated income and employment through backward and forward linkages in the output structure. It comprises information on production functions, and (primary and secondary) income distributions. This allows for internal variables (e.g., output, income, payments to factors) to be derived from changes in exogenous variables. As such, Leontief models are used to assess the potential impacts of changes in output structure on income distribution and job creation.

2.2. *Agricultural structure*

Agriculture is a core sector in Egypt, and its main crops are wheat, fodders, and vegetables (winter), rice, other crops, sugar cane and vegetables (summer) and year-round fruits. Production factors requirement and productivity vary significantly across seasons and crops. For

[1] The validity of the input-output tables, and therefore their natural extensions, the SAMs, tends to be applicable in the medium term for economies with a fairly stable productive structure, such as Egypt. Therefore, despite using more recent data, when available, would provide a more accurate description of the Egyptian economy, the use of a 2008/09 SAM does not bias the results of the analysis.

Table 1 - Macro SAM for Egypt 2008/09, billion LE*.

	Commodities	*Activities*	*Labour*	*Capital*	*HH*	*N.P.I.S.H*	*Gov*	*Direct Taxes*	*Indirect Taxes*	*Enterprises*	*S/I*	*Trade Margins*	*ROW*	*TOTAL*
Commodities		756.04			825.15	5.65	124.04				207.21	154.72	258.89	2331.71
Activities	1859.18													1859.18
Labour		264.14												264.14
Capital		807.69												807.69
HH			264.14	268.53			62.08			291.45			23.20	909.40
N.P.I.S.H				0.20						6.34			0.70	7.24
Gov				4.36				86.30	57.87				9.56	158.09
Direct Taxes					14.00					72.30				86.30
Indirect Taxes	26.56	31.31												57.87
Enterprises				476.10									4.28	480.38
S/I					55.78	1.59	-28.03			110.29			67.58	207.21
Trade Margins	154.72													154.72
ROW	291.24			58.50	14.46									364.21
TOTAL	2331.71	1859.18	264.14	807.69	909.40	7.24	158.09	86.30	57.87	480.38	207.21	154.72	364.21	

*Note: *LE is the abbreviation for the French caption of Egyptian pounds - livre égyptienne. Raw data are expressed in million LE. The transaction values presented in the final, extended SAM are expressed in billion LE. In the course of the SAM construction, a scaling factor of 1000 was used. Source: Osman et al., 2015b.*

example, in the summer season, when the most water-intensive crops (e.g., rice and cotton) are cultivated, more than half of the available Nile waters are consumed, Table 2.

Figure 1 depicts productivity for Nile-related production factors: Nile water, and Nile land. Overall, water has the highest productivity, particularly in the winter, and it is more pronounced in the seasonal vegetables sectors. While this pattern is applicable to winter crops, land productivity for summer sugar cane and winter fodders are the highest in comparison with the rest of crops. In the short *Nili* season, water productivity for rice is notable.

3. Modelling agricultural productivity

To conduct a rigorous analysis of multiplier effects for various productivity shocks, the conventional SAM multiplier analysis is modified to incorporate supply constraints on seasonal agricultural activities.

3.1. *Conventional multipliers*

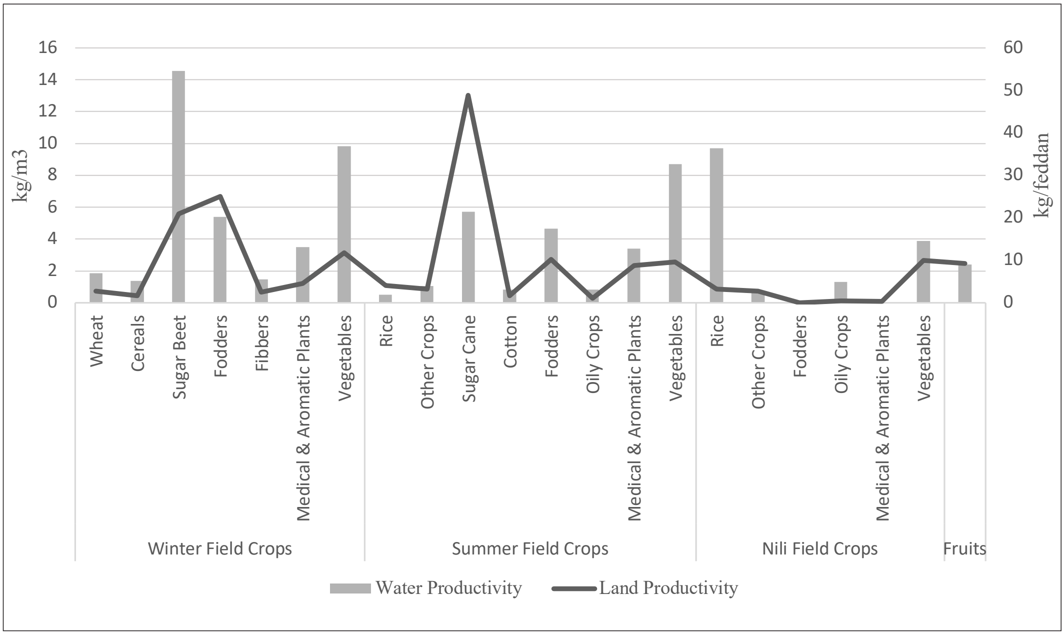
Despite its simplicity, conventional linear multipliers analysis is useful to describe the Egyptian economy in general, and the agricultural sector and irrigation systems in particular.

Table 2 - Egypt agricultural structure and water requirements.

	Cultivated Land		*Water*		*Production*			*Water Requirement*	
	Area (1000 feddan)	%	Water Usage (million m^3)	%	Production (1000 ton)	%	Yield (ton/ feddan)	Water / Land Ratio (m^3 /feddan)	Water Intensity (million m^3/1000 ton)
Winter Crops	**6,734**	**43.14**	**15,892**	**33.78**	**78,349**	**54.54**	**11.63**	**2,360**	**0.20**
Wheat	3,133	20.07	4,556	9.68	8,493	5.91	2.71	1,454	0.54
Cereals	170	1.09	199	0.42	275	0.19	1.62	1,171	0.72
Sugar Beet	362	2.32	514	1.09	7,486	5.21	20.68	1,420	0.07
Fodders	2,040	13.07	9,391	19.96	50,613	35.23	24.81	4,603	0.19
Fibbers	16	0.10	27	0.06	40	0.03	2.50	1,688	0.68
Medical & Aromatic Plants	48	0.31	61	0.13	214	0.15	4.46	1,271	0.29
Vegetables	965	6.18	1,144	2.43	11,228	7.82	11.64	1,185	0.10
Summer Crops	**5,384**	**34.49**	**23,056**	**52.57**	**36,637**	**35.67**	**6.80**	**4,282**	**0.63**
Rice	1,410	9.03	10,839	23.04	5,667	3.95	4.02	7,687	1.91
Other Crops	2,129	13.64	6,461	13.73	6,716	4.68	3.15	3,035	0.96
Sugar Cane	326	2.09	2,766	5.88	15,765	10.97	48.36	8,485	0.18
Cotton	520	3.33	1,038	2.21	853	0.59	1.64	1,996	1.22
Fodders	702	4.50	1,530	3.25	7,130	4.96	10.16	2,179	0.21
Oily Crops	273	1.75	361	0.77	298	0.21	1.09	1,322	1.21
Medical & Aromatic Plants	24	0.15	61	0.13	208	0.14	8.67	2,542	0.29
Vegetables	1,539	9.86	1,679	3.57	14,607	10.17	9.49	1,091	0.11
Nili Crops	**675**	**4.33**	**2,225**	**4.73**	**3,908**	**2.72**	**5.79**	**3,298**	**0.57**
Rice	3	0.02	1	0.00	10	0.01	3.23	333	0.10
Other Crops	360	2.31	1,563	3.32	999	0.70	2.78	4,342	1.56
Fodders	82	0.53	0	0.00	653	0.45	7.97	0	0.00
Oily Crops	3	0.02	1	0.00	1	0.00	0.43	333	0.77
Medical & Aromatic Plants	1	0.00	82	0.17	0	0.00	0.29	117,143	410.00
Vegetables	226	1.45	578	1.23	2,244	1.56	9.93	2,558	0.26
Fruits	**1,277**	**8.18**	**4,197**	**8.92**	**10,144**	**7.06**	**7.94**	**3,287**	**0.41**
Total	**15,609**	**100**	**47,049**	**100**	**143,645**	**100**	**9.20**	**3,014**	**0.33**

Note: A feddan is a non-metric measurement unit of land area equivalent to 1.037 acres, 0.420 hectares or 4,220 m^2. Source: Compiled by the authors.

Figure 1 - Productivity for Nile-related production factors.



Note: Water productivity is calculated as the ratio between production (in metric tons) and water usage (million m³), while land productivity is calculated as the ratio between production and area (1000 feddan). Source: Compiled by the authors.

Osman *et al.* (2015a), following Leontief (1936), and Pyatt & Round (1979), estimate conventional linear multipliers for the Egyptian economy,

$$\mathbf{x_n} = \mathbf{A}_\mathrm{n}\mathbf{x}_\mathrm{n} + \mathbf{y}_\mathrm{n} = (\mathbf{I} - \mathbf{A}_\mathrm{n})^{-1}\mathbf{y}_\mathrm{n} = \mathbf{M}\mathbf{y}_\mathrm{n} \quad (1)$$

where $\mathbf{x}_\mathrm{n}$ is the vector of total gross output of endogenous accounts; $\mathbf{y}_\mathrm{n}$ is the corresponding vector of total final demand; $\mathbf{A}_\mathrm{n}$ is the matrix of average expenditure propensities of endogenous accounts, whose components a_{ij} represent the expenditure on account *i* for each unit of expenditure or total employment in *i*; $\mathbf{y}_\mathrm{n}$ is the column vector that counts the total income flow received by endogenous accounts from exogenous accounts (usually total or partial final demand); and **M** is the SAM accounting multipliers matrix.

Osman *et al.* (2015a) identify ‘other crops’, namely wheat (winter), rice and ‘other crops’ (summer), and seasonal vegetables as the key agricultural activities in the primary sector and select ‘food services’ among the sectors with strong backward linkages. In addition, the study highlights the positive effects on most agricultural activities (e.g., ‘accommodation and food services’), manufacturing activities, education and ‘social protection’. Another noteworthy positive relationship is the estimated between ‘environmental protection’ and services activities.

Results derived from the conventional multiplier analysis should be taken with a grain of salt. The implicit assumption, in accounting multipliers, that all productive sectors are demand-driven with a perfectly elastic supply is not valid for all sectors. This assumption is particularly unrealistic for agriculture in developing countries, where manifest supply constraints are imposed (Rich *et al.*, 1997; Haggblade *et al.*, 1991; Subramanian & Sadoulet, 1990; Lewis & Thorbecke, 1992). Ignoring these constraints leads to overestimated multiplier results (Haggblade *et al.*, 1989; Lewis & Thorbecke, 1992).

A mixed multiplier analysis relaxes this assumption and specifies activities with supply constraints, where the output could only expand with external improvements in production factors's productivity. This allows for rigorous multiplier analysis and robust estimation of the impacts on the rest of the economy.

3.2. *Mixed multipliers model*

Two fundamental reasons justify the use of mixed multplier analysis. Firstly, it provides accurate estimates of the impacts generated by hypothetical demand-driven shocks in the non-constrained sectors. Secondly, it measures the effects of external shocks in sectors with constrained outputs, through improvements of productivity or more efficient use of the available production factors. As such, a mixed multiplier analysis evaluates the effects of an exogenous increase in agricultural output, induced by a more efficient use of water and higher productivity, on the Egyptian economy through backward and forward linkages.

A mixed multiplier analysis, firstly developed by Miller & Blair (1985) in the context of input-output (I-O) models, extends the analysis to the SAM-Leontief models (Subramanian & Sadoulet, 1990; Lewis & Thorbecke, 1992). The results obtained by the last two studies are then generalized by Parikh & Thorbecke (1996). McDonald & Punt (2002) conduct a mixed multiplier analysis of the implications of trade liberalisation for agriculture in South Africa under the supply constraints condition of limited land.

The mixed multiplier model identifies two types of sectors: unconstrained sectors, which respond to changes in final demand, and constrained sectors with a fixed output which, consequently, cannot freely respond to increases in final demand. In our analysis, agriculture, Nile water, and land accounts have fixed output but are still considered endogenous. The difference as opposed to traditional multipliers is that, for constrained sectors, it is not final demand that is fixed and can be exogenously modified to influence the output but, on the contrary, the output is fixed and its exogenous alteration affects the final demand of these sectors and the output of the rest of the activities.

Nile water and land supply in different irrigation seasons are specified to be fixed at their baseline levels. Agriculture output is exogenous and could only increase via external shocks in productivity. The model is presented as follows,

$$\begin{bmatrix} \mathbf{x}_{nc} \\ \mathbf{y}_c \end{bmatrix} = \begin{bmatrix} (\mathbf{I}-\mathbf{A}_{nc}) & \mathbf{0} \\ -\mathbf{R} & -\mathbf{I} \end{bmatrix}^{-1} \begin{bmatrix} \mathbf{I} & \mathbf{Q} \\ \mathbf{0} & -(\mathbf{I}-\mathbf{A}_c) \end{bmatrix} \begin{bmatrix} \mathbf{y}_{nc} \\ \mathbf{x}_c \end{bmatrix} = \mathbf{M}_m \begin{bmatrix} \mathbf{y}_{nc} \\ \mathbf{x}_c \end{bmatrix} \quad (2)$$

where $\begin{bmatrix} \mathbf{A}_{nc} & \mathbf{Q} \\ \mathbf{R} & \mathbf{A}_c \end{bmatrix} = \begin{bmatrix} \mathbf{Z}_{nc,nc} & \mathbf{Z}_{nc,c} \\ \mathbf{Z}_{c,nc} & \mathbf{Z}_{c,c} \end{bmatrix} \begin{bmatrix} \hat{\mathbf{x}}_{nc}^{-1} & 0 \\ 0 & \hat{\mathbf{x}}_c^{-1} \end{bmatrix}$

here, using the subscript *c* (constrained) to distinguish accounts with exogenous output than not constrained (*nc*) accounts; **x** and ***y*** the output/availability and the income vectors respectively; and **z** is the submatrix of endogenous accounts.

Following Pyatt and Round (1979), and Mainar-Causapé *et al.* (2018), public sector, savings and investment, and the rest of the world are the exogenous accounts.

Thus, $\mathbf{M_m}$ reflects the effect of the existing restrictions in agriculture output and Nile water and land factors. This restriction entails a logical decrease in the values of the accounting multipliers calculated for the remaining activities, commodities, or factors.

Since the main issue to analyse is the effect of shocks on the output of agricultural activities, only the corresponding values for these agricultural activities in columns will be taken from the entire $\mathbf{M_m}$ matrix. The values in the rows of the rest of the activities give the effect on the output of non-agricultural activities, while the values in the rows of households and government show the effect on the income of these institutions.

To obtain employment multipliers, a vector **e** that contains the ratios of employment per output value is required. The diagonal version of **e**, matrix **E**, is multiplied by the sub-matrix of $\mathbf{M}_m$ which incorporates the rows corresponding to the productive accounts (and agriculture accounts as columns), called $\mathbf{M}_m$*. The expression of the employment multiplier matrix, $\mathbf{M_m(e)}$, is given as:

$$\mathbf{M}_m(\mathbf{e}) = E\ M_m^* \quad (3)$$

Each element *i,j* in $\mathbf{M_m(e)}$ indicates the increment of the employment of the account *i* generated by an unitary increase in output of account *j*.

3.3. *External shocks*

As previously mentioned, agriculture in Egypt is constrained by limited water resources and a fully exploited land. Under these conditions, agricultural output can only expand with exogenous improvements in Nile water and/or land productivity and efficiency. Indeed, Gohar & Ward (2011) argue that a more efficient allocation of Nile water induces expansions in agriculture output and generates a 28% increase in national farm income.

Our analysis examines how an increase in agricultural production could affect other sectoral outputs, employment, and household income. Based on the agricultural structure (Sub-section 2.2), it quantifies the impacts of an increase in the agricultural output, induced by exogenous improvements in the use of Nile water and land, on non-primary sectors' output, employment, and household income.

The improvements in irrigation efficiency and productivity in this model are exogenous, given the specific characteristics of SAM models. The interesting question related to how irrigation efficiency and productivity could be improved falls beyond the scope of this research. An increased efficiency cannot be achieved without increasing investment and expenditure in research and development. These costs will have wider economic effects depending on the amount needed to achieve the simulated productivity shocks, the financing of the costs and the secondary effects of these expenditures on the agricultural sector. The lack of the cost-related data might produce a slight overestimation of the results. Previous analyses conducted for Egypt (Osman *et al.*, 2019) demonstrate that improving irrigation water quality has strong positive economy-wide impacts which compensate for the costs associated to the water quality improvement projects. With noticeable expansions in high-value crops (i.e., fruits, seasonal vegetables, and rice), income increases by 4%.

4. Mixed multipliers results

4.1. *Output and income multipliers*

The multiplier values (Table 3) refer to changes in non-agricultural outputs, as well as household and government income, in response to an exogenous unitary increase in crop output across the seasons. Sectors with backward and forwards linkages greater than one are the key sectors in the economy (Chenery & Watanabe, 1958; Rasmussen, 1956). Sectors with strong backward linkages have a high demand for other sectors' output, and, as a consequence, they stimulate those backward sectors.

Almost all seasonal crops have strong multiplier effects on non-agriculture output and, to a lesser extent, on household income. This is particularly true for cotton, rice, fodders, vegetables, and fruits. Multiplier effects on government tax revenue are trivial, as seasonal crops display multiplier values lower than one.

Cotton (the Egyptian 'white gold') has a strong forward linkage with the textile industry, the manufacturing sector, that is a main source of farmers' income, and export revenues. The textile industry contributes to 3% of GDP, absorbs around one-third of the industrial labour force, and accounts for 15% of non-petroleum exports.

Rice has also great importance for the country's output and income structures and is a major export crop. It accounts for more than 6% of the agricultural output; a substantial share of rice production is exported, contributing to more than 10% of the total agricultural exports.

Vegetables and fruits are crucial sectors for the Egyptian economy, comprising 26% and 7% of agricultural GDP respectively. Fruits contribute virtually to half of the agricultural exports. In addition, processed and preserved vegetables and fruits are among the largest manufacturing industries in Egypt. These explain the significant direct and indirect effects of vegetables and fruits on the outputs of other sectors and the economy-wide income.

These results are compatible with findings by Siam (2013). The author uses 2009/10 SAM for Egypt and finds high backward linkages for crop and livestock production and high forward linkages for trade and services, social services, agro-vegetal and oil & extracts, while food industrial production exhibits high backward and forward linkages.

Figure 2 depicts changes in output (including agricultural and non-agricultural sectors)

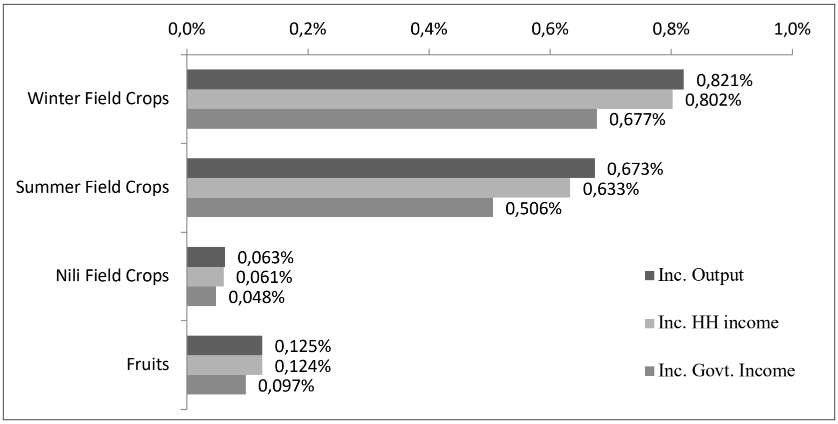
Table 3 - Output and income multipliers.

	Output non-agricultural	*HH income*	*Govt. tax revenue*
Winter Field Crops	**1.10**	**1.00**	**0.15**
Wheat	1.09	0.93	0.13
Cereals	1.12	0.86	0.11
Sugar Beet	1.02	0.95	0.13
Fodders	1.10	1.06	0.16
Fibbers	1.08	0.97	0.13
Medical & Aromatic Plants	1.10	0.99	0.14
Vegetables	1.13	1.05	0.16
Summer Field Crops	**1.05**	**0.94**	**0.13**
Rice	0.95	0.86	0.12
Other Crops	1.02	0.89	0.11
Sugar Cane	1.05	0.95	0.14
Cotton	1.21	1.06	0.14
Fodders	1.12	1.06	0.16
Oily Crops	1.05	0.97	0.13
Medical & Aromatic Plants	1.09	0.98	0.14
Vegetables	1.08	0.98	0.14
Nili Field Crops	**1.08**	**0.97**	**0.13**
Rice	1.13	1.04	0.13
Other Crops	1.04	0.91	0.12
Fodders	1.15	1.08	0.16
Oily Crops	0.95	0.85	0.11
Medical & Aromatic Plants	1.03	0.91	0.13
Vegetables	1.10	1.01	0.15
Fruits	**1.12**	**1.04**	**0.14**

Source: Compiled by the authors.

as well as household and government income induced by a 10% increase in crop production. The latter is generated by an improvement in water productivity. Results show a systematic pattern across all seasons, when changes are in descending order, starting with the highest changes in total output followed by changes in household and government income. Productivity improvements in winter field crops (particularly wheat, fodders and vegetables) show the biggest changes (Table 4). These three winter crops are of great importance for expanding output and generating household and government income. In the summer, vegetables and, to a lesser extent, other crops and rice generate notable changes.

Figure 2 - Total output, household and government income (% change).



Source: Compiled by the authors.

Table 4 - Total output, household and government income (% change).

	Inc. Output	*Inc. HH income*	**Inc. Govt. Income**
Winter Field Crops	**0.82%**	**0.80%**	**0.68%**
Wheat	0.29%	0.26%	0.21%
Cereals	0.01%	0.01%	0.01%
Sugar Beet	0.03%	0.03%	0.02%
Fodders	0.26%	0.27%	0.24%
Fibbers	0.00%	0.00%	0.00%
Medical & Aromatic Plants	0.00%	0.00%	0.00%
Vegetables	0.22%	0.23%	0.19%
Summer Field Crops	**0.67%**	**0.63%**	**0.51%**
Rice	0.13%	0.11%	0.09%
Other Crops	0.15%	0.14%	0.10%
Sugar Cane	0.06%	0.05%	0.05%
Cotton	0.05%	0.05%	0.04%
Fodders	0.04%	0.04%	0.03%
Oily Crops	0.02%	0.02%	0.02%
Medical & Aromatic Plants	0.00%	0.00%	0.00%
Vegetables	0.23%	0.22%	0.18%
Nili Field Crops	**0.06%**	**0.06%**	**0.05%**
Rice	0.00%	0.00%	0.00%
Other Crops	0.02%	0.02%	0.02%
Fodders	0.00%	0.00%	0.00%
Oily Crops	0.00%	0.00%	0.00%
Medical & Aromatic Plants	0.00%	0.00%	0.00%
Vegetables	0.03%	0.03%	0.03%
Fruits	**0.12%**	**0.12%**	**0.10%**

Source: Compiled by the authors.

4.2. *Employment multipliers*

Agricultural employment multipliers are higher than in non-agricultural multipliers (Table 5). Agricultural employment multipliers do not vary significantly since the same employment is conducted uniformly across crops. Nevertheless, various backward and forward linkages with industries generate slightly different multipliers.

The highest employment multipliers are generated in cotton, cereals, fodders, fruits and vegetables. As explained before, cotton, with the forward-linked textile industry, provides employment to several million Egyptian workers. In addition, cereals, fruits, and vegetables have strong forward linkages with the food products and beverage production sector, which absorbs 25% of the total manufacturing employment, making it the largest employer within the manufacturing sectors.

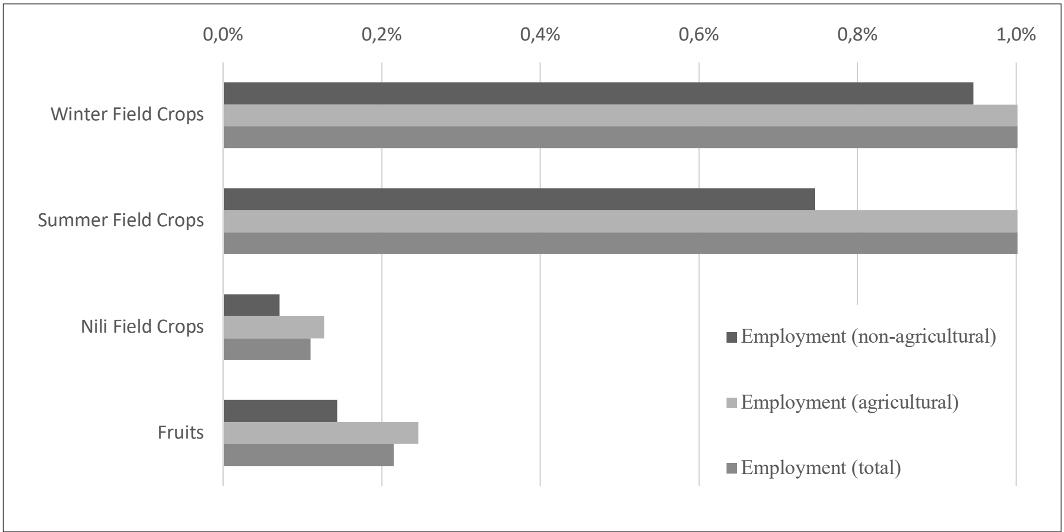
Table 5 shows the number of jobs generated by an increase of 10% in agricultural output associated to an exogenous increase of water productivity. Winter field crops generate the highest number of jobs. This result is mainly due to wheat, fodders, and vegetables. In addition, some of the summer field crops achieve high values of generated jobs,

Table 5 - Number of generated jobs (employees).

	Non-agricultural	*Agricultural*	*Total*
Winter Field Crops	**65,042**	**262,041**	**327,083**
Wheat	22,549	91,933	114,481
Cereals	856	3,381	4,236
Sugar Beet	2,412	10,584	12,996
Fodders	21,089	84,075	105,165
Fibbers	118	485	603
Medical & Aromatic Plants	348	1,400	1,748
Vegetables	17,670	70,183	87,853
Summer Field Crops	**51,314**	**220,613**	**271,927**
Rice	9,001	43,116	52,117
Other Crops	11,095	49,554	60,649
Sugar Cane	4,410	18,929	23,339
Cotton	4,252	15,590	19,841
Fodders	3,069	12,100	15,169
Oily Crops	1,816	7,758	9,574
Medical & Aromatic Plants	135	547	681
Vegetables	17,536	73,020	90,556
Nili Field Crops	**4,868**	**20,381**	**25,249**
Rice	46	185	231
Other Crops	1,790	7,856	9,646
Fodders	374	1,438	1,812
Oily Crops	8	40	49
Medical & Aromatic Plants	3	12	15
Vegetables	2,646	10,849	13,496
Fruits	**9,891**	**39,401**	**49,292**
Total	**131,115**	**542,436**	**673,551**

Source: Compiled by the authors.

Figure 3 - Employment (% change).



Source: Compiled by the authors.

except in the case of oily crops and medical and aromatic plants. The sectors with the highest direct increases in employment are also those with the highest forward and backward linkages in other non-agricultural industries.

Figure 3 shows changes in employment induced by a 10% increase in water productivity. Improving productivity for winter and summer crops generates an increase in employment, mainly in the agriculture sector, higher than 1%. Sectoral results show that wheat, fodders (in the winter) vegetables, other crops, and rice (in the summer) are the most important sectors to generate employment.

4.3. *Results robustness*

The correlations between water productivity and the generated changes in total output (left) and in employment (right) (Figure 4) help examine the robustness of the results.

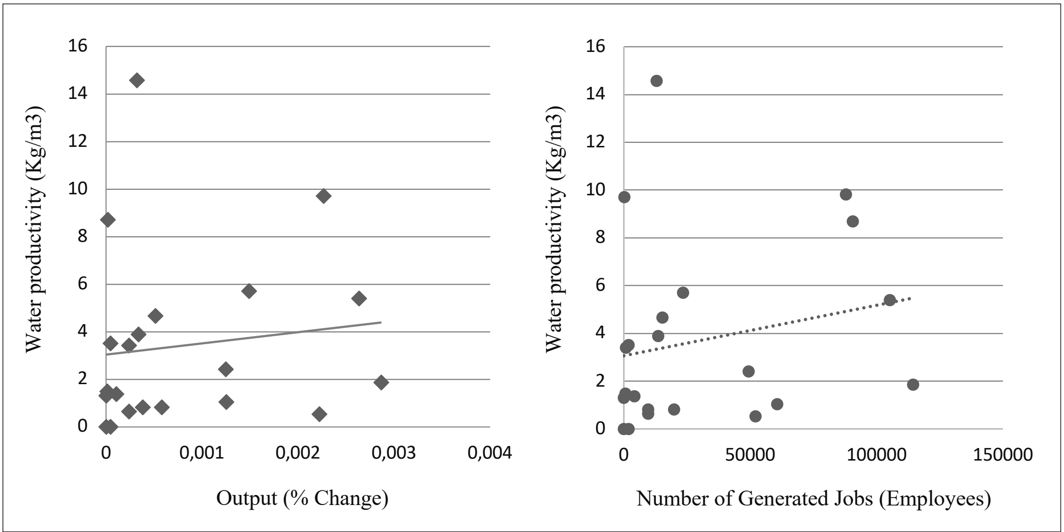
Water productivity is positively correlated with total output and employment. In other words, the more productive is water, the higher are the increases in total output and in employment. This implies that improving water productivity is important not only for increasing the agricultural output, but also for the overall economy to expand through backward and forward linkages. In addition, improving water productivity helps in reducing unemployment in Egypt.

5. Conclusions and discussions

Egypt faces a shortage of freshwater resources; the problem is predicted to significantly aggravate with the country's rapid population growth rate and under the adverse climate change issues. With limited availability of Nile water and land, the agricultural output will increase only by improving productivity and promoting more efficient use of these scarce resources. Good news is that by investing in infrastructures for water and land, and by enhancing agriculture productivity the country may produce sizable profits not only within the sector, but also throughout the rest of the economy via several multiplier effects.

The paper conducts a mixed multiplier analysis for the Egyptian agriculture sector. It uses 2008/09 SAM extended with detailed accounts of seasonal agricultural sectors showing constrained water and land supply. By simulating improvements in water and land productivity, output, income, and employment multipliers are calculated.

Figure 4 - Correlation lines.



Source: Compiled by the authors.

The results show that the highest changes in output, income, and employment occur in winter field crops. This is particularly the case for wheat, fodders, and vegetables. In addition, rice, the main summer crop, generates significant multiplier effects. A similar seasonal pattern is depicted: where the highest changes occur in sectoral outputs with descending changes in household and government income.

The Egyptian economy is under continuous strain with structural problems in the labour market. These include high unemployment rates, an inefficiently large public sector with excessive employment, a sizable informal unemployment, and mismatches between demanded skills and labour supply. Our analysis measures employment multipliers and numbers of generated jobs under a 10% increase in agricultural output. Agricultural employment multipliers are not only higher than their non-agricultural counterparts, but they also have remarkable direct and indirect impacts on the overall economy; as a matter of fact, improving Nile water and land productivity by only 10% could generate jobs for virtually 674 thousand Egyptians.

Most of the policies based on agricultural productivity analysis have focused on the sector's direct contribution to the Egyptian economy. By explicitly quantifying the backward and forward linkages for various seasonal crops, our paper provides new insights about the magnitude of the sector's direct, indirect, and induced effects on output, income, and employment. Our results demonstrate the significance and importance of policies that aim at improving Nile water and land productivity, enhancing irrigation efficiency, and optimizing the use of agricultural natural resources. Even though the costs of the improvement of irrigation efficiency and productivity are not measured specifically in this research, agriculture shows great potential for the rest of the Egyptian economy and could generate noteworthy socio-economic effects, which will compensate for the costs. Agricultural productivity-led policies generate economy-wide output expansions, which create more jobs and income. Hence, the sector could potentially be a key driving force of Egypt's sustainable development strategy. This result could be achieved by increasing public investments in agricultural research and expansion so as to develop new technologies and increase the total agriculture productivity (see also Fuglie *et al., 2020).*

Acknowledgements

The authors would like to thank the two anonymous reviewers for their valuable remarks and comments.

Disclaimer

The views expressed in this paper are the sole responsibility of the authors and do not necessarily reflect those of the European Commission.

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Water Users Associations and irrigation water use efficiency in costal oases areas in Gabès, Southeastern Tunisia

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DOI: 10.30682/nm2101b
JEL codes: Q12, Q25, R15

Abstract

The objective of this study was to measure the efficiency level of Water Users Associations (WUAs) in the coastal oases of Gabès (Southeastern Tunisia) and to assess its main determinants. First, an input-oriented data envelopment analysis (DEA) was used to measure the relative efficiency scores of WUAs and to evaluate the management and maintenance costs sub-vectors efficiencies separately through a mathematical modification in the initial DEA specification. In a second stage, critical determinants of sub-vector efficiency are determined by applying a Tobit model. A key finding of the study is that WUAs are clearly inefficient. Results show that on average, 36% of the used inputs (management and maintenance costs) could be saved if the WUAs operated on the frontier. The inefficiency found can be mainly attributed to the number of water pumping stations managed, the ratio of water losses and the WUAs' age. The results also show a discrepancy between the technical efficiency values calculated under the CRS and VRS assumptions, resulting in a 20% scale inefficiency. The study also revealed that the sub-vector inefficiency of WUAs is linked more to engineering inefficiencies than to inefficiencies in their management.

Keywords: *WUA, Coastal oases, DEA method, Technical efficiency, Sub-vector efficiency, Tunisia.*

1. Introduction

Water scarcity has become a main challenge for the world, with increasing demand resulting from the growing population, accelerating economic development, and rapid urbanization (Yilmaz *et al.*, 2009; Zhou et *al.,* 2017). Globally, irrigation water is becoming an increasingly scarce resource for agriculture in Tunisia and in many regions of the world (Hamza, 2008; Abdelhafidh and Bachta, 2016; Ben Nasr and Bachta, 2018; Mahdhi *et al.*, 2011; Mahdhi and Sghaier, 2013; Zema *et al.*, 2018; Mahdhi *et al.*, 2019). Tunisia is placed in the category of the least water resources-endowed countries in the Mediterranean basin (ITES-Institut Tunisien des études stratégiques, 2011; 2014; Elloumi, 2016). Overall, water reserves in the country are estimated at 4.7 billion m^3/year, of which 2.7 bil-

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lion m^3 comes from annual rivers in the north, 0.7 billion m^3 from groundwater in the Centre, plains and coastal areas, and about 1.3 billion m^3 from the deep groundwater mainly in the south (MA-Ministry of Agriculture and Water Resources, 2016). Water resources are unevenly distributed across the country, with around 60% in the north, 18% in the center and 22% in the south (MA, 2016). Water resources with a salinity lower than 1.5 g/liter are distributed as follows: 72% of surface water resources, 8% of shallow groundwater and 20% of deep groundwater (Louati, 2008; MA, 2013).

The agricultural sector, which accounts for approximately 8% of the GDP, is the largest consumer of water, and irrigation accounts for some 85% of water withdrawals from 212 shallow aquifers (containing 719x10^6 m^3) and 267 deep aquifers (MA, 2016; INS-Institut National de Statistique, 2016). In 2016, about 444 thousand hectares (9% of useful agricultural land) are irrigated in Tunisia (MA, 2016). Irrigated agriculture represents 37% of the output value derived from the agricultural sector, 20% of exports, and 27% of agricultural employment (MA, 2016). Irrigated areas provide 95% of horticultural crops and 30% of dairy production (MA, 2013). Moreover, the efficiency of the irrigation networks is relatively weak, estimated at approximately 50% (Bachta and Ghersi, 2004). Therefore, during recent decades, concerns regarding the efficient use of water resources in the country have been raised (Belloumi and Matoussi, 2007; Mahdhi and Sghaier, 2013; Frija *et al*., 2014; Abdelhafidh and Bachta, 2016). These concerns have been addressed particularly through significant investments, reaching 8,3% of total investments in the government's Development Plan XII (2011-2015) and through the transfer of the management of collective irrigation schemes to the users through the creation of water user associations (WUAs) (MA, 2010; Makkaoui and Dubois, 2010; Mahdhi and Sghaier, 2017). The WUAs have been created through government investments, but they are responsible to ensure the collection of water fees as well as service-related fees (e.g., infrastructure maintenance) (Bachta and Zaïbet, 2007; Romagny and Riaux 2007; Makkaoui and Dubois, 2010; Ben Nasr and Bachta, 2018).

The number of WUAs has increased from about 100 in 1993 to 1160 in 2009, managing around 220 000 hectares of irrigated lands (MA, 2016; Elloumi, 2016). Annually, each WUA is responsible for the elaboration of its own budget, as well as for choosing the water price and deciding whether payments are to be made on the basis of water volumes to be produced or distributed. Furthermore, WUAs establish the amount of projected investments and the operation and maintenance charges. Financially, WUAs perform the following tasks: operation and maintenance of canals, repairing of various infrastructures, the management of the association and investments (Frija *et al*., 2009; Ben Nasr and Bachta, 2018).

The transfer of the management of collective irrigation schemes to WUAs has tried to stimulate water productivity, provide the farmers' participation, and thereby simultaneously achieving economic and ecological benefits (Romagny and Riaux, 2007; Zhang *et al*., 2013; Özmen and Kamanb, 2015; Zema *et al*., 2015). However, the objectives of achieving a positive impact on resource productivity, equity, full cost recovery and environmental sustainability are not always met (Romagny and Riaux, 2007; Makkaoui and Dubois, 2010; Frija *et al.*, 2014; Ben Mustapha *et al.*, 2016; Abdelhafidh and Bachta, 2016; Ben Mustapha and Fyasse, 2017). In Tunisia, only 25% of WUAs succeeded in covering their entire operation and maintenance costs, while 25% of them covered even less than 50% and were still subsidized by the government (Al Atiri, 2007; Marlet and Mnajja, 2017). However, problems differ from one WUA to another, with only some associations eligible to be considered efficient (Al Atiri, 2007; Ben Mustapha *et al.*, 2015; Marlet and Mnajja, 2017; Ben Mustapha and Fyasse, 2017).

In oases areas, WUAs are still facing a wide range of financial, technical, and organizational constraints (Romdahne and Abdelathim, 2008; Abdedayem, 2009; Ghazouani *et al.*, 2012; Ouneis, 2018). Among the main problems, there are: insufficient maintenance and repair services, challenges in the collection of water fees, the need for rehabilitation of facilities, inadequacy of new investments and failure to encourage producers to participate in the management of irrigation systems (Romdhane *et al.*, 2006; Romdahne and Abdelathim, 2008; Boukchina and Abdedayem, 2008; Abdedayem, 2009; Carpentier, 2017; Ouneis, 2018). The efficiency analysis revealed that some WUAs are suffering from small-scale management (Belloumi and Matoussi, 2007; Ghazouani *et al.*, 2012; Emlyaeih, 2016). A major reorganization is deemed necessary to further improve the management of WUAs for the efficient water use and farmer welfare. This paper tries to address the relative performance of WUAs in terms of management and engineering efficiencies in oases areas of Gabès (Southeastern Tunisia), and to identify critical technical and organizational determinants of efficiencies. Many methodologies can be used for this purpose, ranging from a simple visual comparison of performance data to relatively sophisticated mathematical methods (Diaz Rodriguez *et al*., 2004; Zema *et al*., 2015; Zema *et al.*, 2018).

This study proposes the use of the data envelopment analysis (DEA) approach. This method is based on linear programming techniques that define the production function and determine the efficiency frontier of a set of decision-making units (DMUs). With a series of inputs and outputs for each irrigation district, DEA allows to assess the relative efficiency of a given district and to obtain the optimal configuration by numerically assigning to each irrigation district its objective (Diaz Rodriguez *et al*., 2004;). In fact, many studies have used the DEA methodology to analyze the organizational efficiency. The applications range from banks, health and educational institutions and forest organizations to airlines and railway companies (Diaz Rodriguez *et al.*, 2004; Mahdhi *et al.*, 2014). To our knowledge, the application undertaken in this paper to assess the efficiency of organizations specializing in water management is still limited (Umetsu *et al.*, 2005; Ghazouani *et al.*, 2012; Mahdhi *et al.*, 2014). In the irrigation and drainage sectors, DEA has often been applied to estimate the production efficiency of large irrigated systems and districts at regional level (Malano *et al.*, 2004; Zema *et al.*, 2015; Zema *et al.*, 2018). In our study, we assume that DEA is not only suitable to apply in the case of water management associations, but moreover, the methodology used allows for the calculation not only of overall but also of sub-vector efficiencies (for alternatives see Oude Lansink *et al*., 2002; Speelman *et al.*, 2007). Management and engineering efficiencies were assessed using the concept of sub-vector efficiencies. As a matter of fact, through management efficiency, we try to express how well a given WUA allocates expenditure to manage the organization and the functioning of the WUA, compared to the rest of the WUAs in the sample. In the same sense, engineering efficiency expresses the performance of a given WUA in allocating expenditure for maintenance tasks, concerning the rest of the WUAs in the sample studied. Maintenance expenditure includes expenses related mainly to the maintenance and repairing of the irrigation network and the pumping stations. Energy costs (for WUAs that pump water from boreholes) and the labor cost of performing the above-mentioned tasks are also included in the maintenance expenditure vector. In a second step, a Tobit model was estimated to provide ideas about local inefficiencies and to determine potential factors affecting the functioning of WUAs. To achieve these objectives, the paper is divided into four separate sections. After the introduction, in section 2, we describe the DEA technique, the Tobit model used in this study as well as the study area and data collection. Results and discussions are presented in the last section, after which the most important conclusions are drawn.

2. Methods and data

2.1. *DEA models*

Based on the work of Farrell (1957), DEA was developed by Charnes *et al.* (1978) as an empirical frontier analysis technique. This method is based on linear programming techniques that define the production function and determine the efficiency frontier of a set of decision-making units (DMUs). According to Farrell (1957), the technical efficiency reflects the ability of a DMU to produce maximum output given a set of inputs or, alternatively, to achieve maximum feasible reductions in input quantities when output values are given. With a series of inputs and outputs for each irrigation district, DEA allows to assess the relative efficiency of a given district and to obtain the optimal configuration by numerically assigning to each irrigation district its objective (Diaz Rodriguez *et al*., 2004). The main advantages of the DEA approach are that it does not require any specific function of production process subject to multiple inputs and outputs, and the efficiency of a DMU is measured by comparing it with an ideal unit that achieves better performance measurement rather than being compared based on average values. Although DEA have some powerful advantages mentioned above, the main limitation in the method is that it does not account for random data error, which can be significant in agriculture (Diaz Rodriguez *et al*., 2004). Additionally, even if the DEA approach has been widely and successfully used in different areas, its application to assess the efficiency of organizations specialized in water irrigation management is limited in the available literature (Diaz Rodriguez *et al.*, 2004; Frija *et al*., 2008; Yilmaz *et al.*, 2009), particularly in costal oases areas. In this study, performances of WUAs in management, operation, and maintenances services (MOM) of costal oases irrigations schemes were evaluated.

The application of the DEA method can be oriented in inputs or outputs, with different objectives set from these two models. The input-oriented model aims to continue producing the same outputs while minimizing the inputs, whereas the output-oriented model aims to maximize outputs using the minimum number of inputs.

Technical efficiency can be decomposed into two components: pure technical efficiency (TE-vrs) and scale efficiency (SE). Scale efficiency relates to the most efficient scale of operation, in the sense of maximizing average productivity. If there is a difference between scores of technical efficiency under Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) for a certain farm, the difference indicates that a farm-scale is inefficient. Scale efficiency measures can be calculated by dividing the total technical efficiency by pure technical efficiency.

One of the analysis options in DEA is a choice between CRS and VRS. CRS assumes that there is no significant relationship between the efficiency and the scale of operation, thus assuming that large WUAs are just as efficient as small ones in converting inputs to outputs. Furthermore, we assume that changes in the organization's inputs can lead to disproportionate changes in its outputs. Therefore, the option of VRS will be chosen in this study. A second option is a choice between input-oriented and output-oriented DEA models. If the focus is to use different resources more efficiently (instead of increasing production), then the suitable model to use is an input-oriented one (Diaz Rodriguez *et al.*, 2004). In our case, it is necessary, as a national objective of the decentralization process, that WUA reaches a cover rate of their expenditures ensuring their sustainability. In addition, the volume of water that a given WUA purchases from the regional water management administration is planned and fixed at the beginning of the year. This value being fixed is necessary for the determination of water rates in the WUA. Therefore, during the agricultural year, the WUA will focus mainly on the minimization of their expenditure. For these reasons, it is estimated that an input-oriented model will be more suitable for our problem. In summary, we chose to estimate the Variable Return to Scale (VRS) efficiencies through BCC (Banker *et al*., 1984) and the input-oriented model.

Following the BCC model, if we consider K DMU (k=1….K) each of them uses N inputs variables xnk (n=1,…,N), for producing M outputs ymk (m=1,…,M). Each DMU0 becomes the reference unit and then we have to resolve the following linear program k times (once for each DMU):

$$Min_{\theta,\ \lambda}\ \theta \qquad (1.1)$$

$$\text{s.t} \sum_{k=1}^{K} \lambda_k y_{m,k} \geq y_{m,0} \qquad (1.2)$$

$$\sum_{k=1}^{K} \lambda_k x_{n,k} \leq \theta . x_{n,0} \qquad (1.3) \qquad \text{(equation 1)}$$

$$\sum_{k=1}^{K} \lambda_k = 1 \qquad (1.4)$$

$$\lambda_k \geq 0 \qquad (1.5)$$

where θ is a variable representing the efficiency of the reference DMU_0, hence the percentage of reduction that each input must be subjected to reach the production frontier. λ_k is a vector of k elements representing the influence of each DMU in determining the efficiency of the DMU0. The term $\sum_{k=1}^{K} \lambda_k y_{m,k}$ indicates the weighted sum of outputs of all DMU, which must be superior or equal to the output of DMU_0 (constraint 2). In constraint 3, θ is the measure of technical efficiency and represents, at the same time, the minimized objective. The estimate will satisfy restriction $\theta \leq 1$ with a value θ=1, indicating a technically efficient farm. Equation 4 consists of the convexity constraint, which specifies a variable return to scale option. The DMUs whose λ values are positive will be the reference set for DMU_0 under study. As a matter of fact, it is the linear combination of those units which will formulate the situation objective needed to become efficient.

It should also be noted that equation 1 has a variable return to scale (VRS) specification, which includes a convexity constraint $\sum_{k=1}^{K} \lambda_k = 1$. Without that constraint, equation (1) would have constant returns to scale specification (CRS). Using that specification, it is assumed that farms are operating at their optimal scale (Oude Lansink and Silva, 2004). In the case of agriculture, increased amounts of inputs do not proportionally increase the amount of outputs. For instance, when the amount of water for crops is increased, a linearly proportional increase in crop volume is not necessarily obtained; one reason why the variable return to scale option might be more suitable for our problem (Diaz Rodriguez *et al.*, 2004).

To calculate the efficiency of the use of an individual input or subset of inputs, the "sub-vector efficiency" concept can be introduced. The sub-vector efficiency measure looks at the possible reduction in the selected subset of inputs holding all other inputs and outputs constant (Oude Lansink *et al.*, 2002; Oude Lansink and Silva, 2004). Using the notion of sub-vector efficiency proposed by Färe *et al.* (1994) in Oude Lansink *et al.*, 2002, technical sub-vector efficiency for variable input t is calculated for each firm i by solving the following linear programming (LP) problem (equation 2):

$$Min_{\theta^t,\lambda} \theta^t \quad (2.1)$$

s.t.

$$\sum_{k=1}^{K} \lambda_k y_{m,k} \geq y_{m,0} \quad (2.2)$$

$$\sum_{k=1}^{K} \lambda_k x_{n-t,k} \leq x_{n,0} \quad (2.3)$$

$$\sum_{k=1}^{K} \lambda_k x_{t,k} \leq \theta^t x_{t,0} \quad (2.4)$$

$$\sum_{k=1}^{K} \lambda_k = 1 \quad (2.5)$$

$$\lambda_k \geq 0 \quad (2.6)$$

(equation 2)

where θ^t is the input *t* sub-vector technical efficiency score for the DMU_0 under study. The measure θ^t represents the maximum reduction of variable input *t* holding outputs and all remaining inputs (*n-t*) constant. All other variables are defined as in program (1). Therefore, the input *t* sub-vector technical efficiency model involves finding a frontier that minimizes the quantity of input *t* (Oude Lansink *et al.*, 2002).

2.2. *Tobit model and variables identification*

After calculating the efficiency measures, the next step is to identify the determinants of inefficiency; something is commonly done by estimating a second-stage relationship between the efficiency measures and suspected correlates of efficiency (Binam *et al.*, 2003). Since the efficiency parameters vary between 0-1, they have censored variables. Consequently, a Tobit model needs to be used (equation 3):

$$\theta^{t*} = \sum_{i=1}^{N} \beta_i Z_i + \varepsilon_i$$

$$\theta^t = \begin{cases} \theta^{t*} if\, 0 \prec \theta^{t*} \prec 1 \\ = 0 \; if \theta^{t*} \prec 0 \\ = 1 \; if \theta^{t*} \succ 1 \end{cases} \quad \text{(equation 3)}$$

where θ^t are the DEA overall, scale, management, and engineering efficiencies used as dependent variables and Z is an (*N**1*) vector of independent variables related to attributes and characteristics of WUAs in the sample. The estimation of the Tobit model is based on maximum likelihood procedures. For Tobit estimates to be consistent, it is necessary that residuals (ε_i) are normally distributed (Holden, 2004). The empirical estimates of the second stage were conducted using the STATA ver. 10.

2.3. *Research area and data collection*

The study area envisaged is part of the coastal oases area of Gabès (Figure 1). In terms of climate, this area is located in the Mediterranean bioclimatic zone (rainy winters and dry summers). Its climate, arid to Saharan, is characterized by irregular and sporadic precipitations (less than 200 mm) (the coefficient of variation exceeds 50%) (Abdedayem, 2009). Groundwater resources are the main source of water that can be exploited in the coastal oases area of Gabès (CRDA Gabès, 2017). These resources are formed by two types of aquifers: the continental, intercontinental and Jeffara slicks. Both aquifers are under intense pressure that continues to increase due to rapid population growth and a remarkable extension of the irrigable potential to 19236 ha and the number of water points equipped with 150 boreholes (CRDA de Gabès, 2017). This overexploitation has been exacerbated in recent years by the spread of illegal wells (Boukchina and Abdedayem, 2008; Abdedayem, 2009). Two subsystems can be distinguished: the subsystem of private irrigated farms is based on surface wells; the subsystem of public irrigation schemes is based on collective tube-wells. The collective irrigated area expands over 13623 ha, representing 70.82% of irrigated area in the governorate of Gabès (CRDA Gabès, 2017). Farmers commonly use collective irrigation systems, managed by about 100 WUAs. Agricultural production is based on crop production and the irrigation system is characterized by surface irrigation methods. According to the CRDA Gabès (2017), the main crops produced in the study area are fruits (58%), vegetables (20%), forage crops (21%) and others (1%). The total agricultural production of this region contributes to nearly 43% of the total regional agricultural production and provides 37% of the agricultural labour force.

Data used in this study refer to 2019 and cover 61 WUAs operating in 8 irrigated districts of Gabès Sud, Mareth, Gannouch, Matmata Eljadida, Hemma, Metouia, Gabès Ouest and Gabès

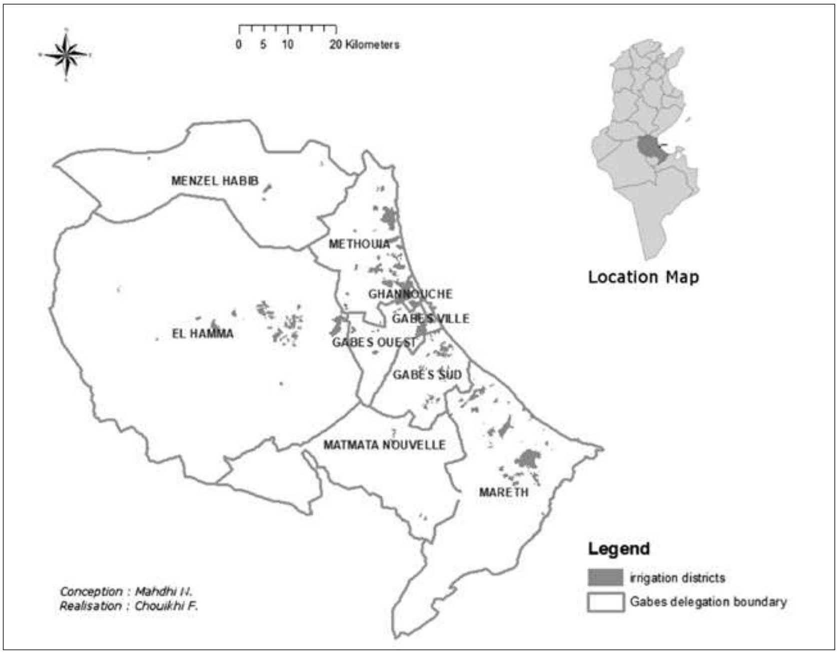


Figure 1 - Location of the study area, irrigation districts.

Ville (Figure 1). These districts cover 43% of the total irrigation areas in the governorate of Gabès. The required data were obtained from the annual reports of the WUAs and the annual monitoring and evaluation reports prepared by regional CRDA. Available data include the volumes of consumed water and the total irrigated areas of each irrigation system, management, maintenance, and repairing cost.

2.4. *Technical, management, and engineering efficiencies*

For the purpose of efficiency analysis, naturally, it is relatively easier to define the inputs and outputs when the irrigation system is assimilated to the DMU. In contrast, the definition of inputs and outputs becomes more complicated when irrigation organizations (WUAs) are considered as the DMUs (Sayin and Yilmaz, 2015). This is particularly associated with the amount of water being taken into account. The main function of irrigation organizations is to make water from their supply available for use by farmers. Therefore, the amount of water provided and other associated variables (i.e., water purchase cost if the water is purchased (Mahdhi *et al.*, 2014)) can be used as inputs, and the amount of water used by farmers and other associated variables can be used as outputs (Malano *et al.*, 2004; Mahdhi *et al.*, 2014; Sayin and Yilmaz, 2015). The size of the irrigated area and the quantity of water distributed per irrigated area are major indicators employed in comparing irrigation organizations in the literature (Malano *et al.*, 2004; Frija *et al.*, 2009). These two outputs are the only constant and stable WUA outputs in the short run. The financial revenue of the WUA, which could be a relevant output to consider, can always change from one year to another according to the objective of the association. Other data related to some productive performance indicators (total gross annual agricultural production in the area managed by the WUA; total annual value of agricultural production; output per unit service area, etc.) was not available. Therefore, the analyses are carried out by considering the output as the annual irrigated area (ha) and the total annual irrigation water delivery per unit irrigated area (m^3 ha^{-1}). Concerning the selection of inputs, according to the database, the WUA expenditures can mainly be divided into management expenditures, maintenance costs, water purchasing costs, labor costs, investments, reimbursements of debts and other expenditures. Given that in our empirical application we try to focus on the relationship between inputs-outputs of the WUAs within a general framework of minimization of irrigation water prices, we choose to aggregate the main financial inputs of the water users' associations into management expenditure, maintenance expenditure, and purchasing water expenditure. These expenditure vectors were always used as inputs for DEA models to analyze the efficiency of organizations (Frija *et al.*, 2009; Sayin and Yilmaz, 2015). Therefore, the analyses are carried out by considering the input as the management costs and maintenance costs, which consist of expenditures made by the irrigation union to maintain its function and internal organizational structure.

Management costs that were considered as inputs include the wages and daily allowances of personnel employed in the irrigation union, vehicle rental charges, vehicle fuel costs, book-keeping and office expenses. The maintenance costs include the wages of personnel employed for maintenance and repairing work, the cost of pumping energy-related, rental charges, fuel expenses and repair costs for vehicles used in maintenance work, and facility maintenance and repair costs. It was expected that the decreasing in management, maintenance, and repair costs would increase the TE.

In the sub-vector management efficiency, only the efficiency of the individual management expenditure input is considered, while holding the rest of inputs and outputs constant. Generally, management expenditures are stable over time (Terraux *et al.*, 2002). The engineering sub-vector efficiency considers the inputs related to the total expenditure on maintenance (labor, energy, and other maintenance expenditures). In the short term, this input gives an idea on the efficiency of the maintenance tasks and on the technical network situation of the WUA. Only the efficiency of this latter individual input will be considered in the calculation of the sub-vector engineering efficiency while keeping the rest of the input vectors constant.

Table 1 - Basic statistics for the data used in the DEA Model.

	Outputs		*Inputs*	
	Irrigated area (ha yr^{-1})	Volume of water distributed ha^{-1} (m^3)	Management costs (TDN/year)	Maintenance costs (TDN/year)
Average	108	7656	14,859	37,828
Standard deviation	81.22	4836	10,714	25,807
Minimum	15	1188	4,250	3,000
Maximum	450	26280	61,400	110,225

Source: Own elaboration based on data survey (2019).

Descriptive statistics concerning the selected outputs and inputs are displayed in Table 1. In the research area, approximately 7271 farmers are operating in a farming area for about 8310 ha. The average irrigated varied between 15 and 450 ha, with an average of 108 ha. The total volume of water distributed and managed by the existing WUAs is around $51x10^6$ m^3 (i.e., around 7656 m^3/ha on average). The management, maintenance and repairing costs depend on the size of WUA, varying from 110,225 TDN to 3,000 TDN.

In the Tobit analyses, various WUA-specific factors are analyzed to assess their influence on the sub-vector management efficiency and the engineering sub-vector efficiency. The explanatory variables in the inefficiency effects include technical, organizational, and administrative characteristics, given by the number of pumping stations managed by the WUA, the ratio of irrigated area, the ratio of water losses and the age of the association, the ratio of adherent to the WUA and to the number of members of the administrative council (Table 2).

Table 2 - Definition for variables used in the Tobit regression.

Variable	*Definition*	*Mean value*
Technical characteristics of the irrigated district		
N. of years in function	Years of experience operating a WUA	32.85
N. of water pumping stations	Number of water pipes. Each pipe is used by a group of farmers	121.66
Resource size (km)	The length of irrigation water carrier (pipelines and surface channel)	22.5
The ratio of water losses	The initial quantity of water held by the WUA/distributed quantity of water	22.3
Irrigation ratio	Area exploited, managed and irrigated/exploitable area	85.12
Administrative and organizational characteristics of the WUA		
The ratio of farmers who are members of WUAs	Number of adherents belonging to the WUA's geographical limits	79
N. of members in the administration council		3.6

Source: Own elaboration based on data survey (2019).

3. Results

3.1. *Efficiency analysis results*

The technical efficiency (equation 1) is estimated using the program DEAP (Coelli, 1996).

Management and engineering sub-vectors efficiencies (equation 3) were modelled in the General Algebraic Modelling System software (GAMS) using the methodology proposed by Speelman *et al.* (2007). Summary statistics of calculated efficiency are presented in Table 3.

For all three efficiencies, the maximum measure found within the sample is unity. The percentage of efficient farms (WUA) represents the share of farms with an efficiency measure of unity. Minimum and maximum values of efficiency scores show considerable variability among farms and districts. The average efficiency provides information about the potential resource savings that could be achieved while maintaining the same output level.

Based on the results of the model efficiency, technical efficiency scores are 51% and 64% respectively, under CRS and VRS assumptions (Table 3). These values indicated that (all) inputs (management and maintenance costs) can be reduced by 49% and 36%, respectively, without any decrease in irrigation services.

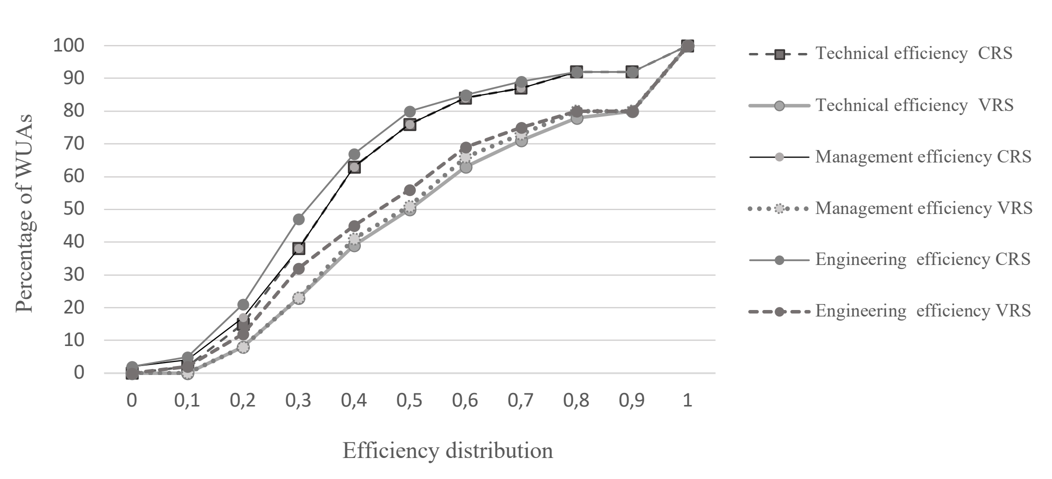
As Table 3 indicates, 80% irrigation schemes are not technically efficient under VRS assumption, and 57.37% of them have technical efficiency scores below the average technical efficiency score of 0.64. At the same time, the average scale efficiency scores of inefficient schemes reached 0.80. Further, 85.24% of the schemes show scale efficiency scores exceeding the average efficiency score. This result suggests that it is due to managerial inefficiency rather

Table 3 - Overall technical, management, and engineering efficiencies under constant and variable returns to scale specification.

Efficiency score (%)	*Overall technical efficiency*		*Management efficiency*		*Engineering efficiency*	
	CRS	*VRS*	*CRS*	*VRS*	*CRS*	*VRS*
	% farms	*% farms*	*% farms*	*% farms*	*% farms*	*% farms*
0-10	0	0	2	0	2	0
10-20	2	0	2	0	3	2
20-30	13	8	13	8	16	10
30-40	23	15	21	15	26	20
40-50	25	16	25	18	20	13
50-60	13	11	13	10	13	11
60-70	8	13	8	15	5	13
70-80	3	8	3	7	4	6
80-90	5	7	5	7	3	5
90-100	0	2	0	0	0	0
100	8	20	8	20	8	20
Mean	0.51	0.64	0.49	0.62	0.46	0.59
Minimum	0.18	0.28	0.063	0.28	0.025	0.17
Scale efficiency	0.80		0.79		0.78	

Source: Own elaboration from model results and data survey (2019).

Figure 2 - Cumulative efficiency distribution for both technical and sub-vectors efficiencies.



Source: Own elaboration from model results and data survey (2019).

than short to medium term uncontrollable operating scale size that is the major problem for most oases irrigation schemes. Improvement of internal management efficiency should be the first option for reducing operating costs for the WUAs. Based on the SE scores, it was concluded that the examined WUAs use 20% extra input because they possess a different scale than the optimum size.

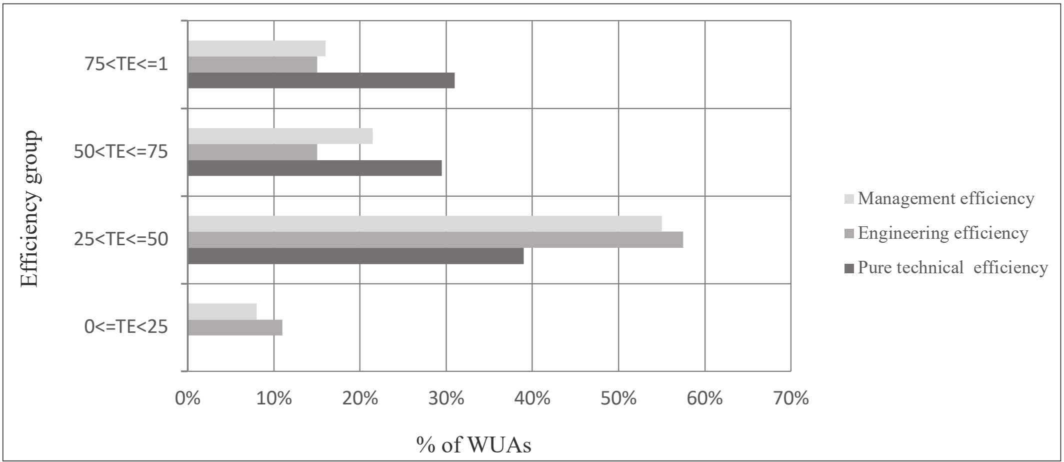
Results show also that management and engineering (maintenance) inefficiencies are larger than the overall inefficiency. Average maintenance efficiency is only 0.46 under CRS and 0.59 under VRS, which is much lower than technical efficiency and exhibits greater variability, ranging from 2.5% and 100%. Mean management efficiency is found to 49% and 62% under CRS and VRS formulation, respectively, which is either lower than technical efficiency and exhibits greater variability, ranging from 6.3% and 100%. Figure 2 depicts the cumulative efficiency distributions, confirming that under CRS and VRS specifications the proportion of WUAs with poor sub-vector management efficiency and engineering sub-vector efficiency is always higher than the proportion of those having poor scores for technical efficiency. This means that WUAs can achieve significant savings in maintenance and management expenditures by improving the way they use the irrigation system and by using more advanced irrigation and agricultural production techniques, even by enhancing the know-how of the techniques and use of the irrigation system.

On the other hand, the study also revealed that the sub-vector inefficiency of WUAs is more linked with engineering inefficiencies than to their inefficiencies in their management. The distribution frequency of the two efficiencies is reported in Figure 3.

Figure 3 shows that nearly 11% of WUAs belong to the group of weak engineering (maintenance) efficiency (between [0; 25%]) while 58% of them belong to the second group (between [25%; 50%]) regarding the same criterion. In both groups, we observe that inefficient WUAs in engineering tasks are more frequent than inefficient WUAs regarding management tasks. As a matter of fact, 69% are inefficient (between [0; 50%]) in engineering, while only 63% of them are inefficient in management. From the same perspective, 37.5% of WUAs belong to the groups of good efficiency (between [50%; 1]) regarding the management efficiency criteria, while only 30% of them belongs to the same group if we consider engineering efficiency.

By improving technical efficiency, management and maintenance costs can be reduced on average by 48.9% and 52.7% per WUA respectively with regard to the good efficiency groups

Figure 3 - The frequency distribution of efficiency scores. re 2 - Cumulative efficiency distribution for both technical and sub-vectors efficiencies.



Source: Own elaboration from model results and data survey (2019).

(between [50%; 1]), and by 62.64% and 64.1% per WUA respectively with regard to the inefficient efficiency groups (between [0; 50%]) (Table 4). When these results will be collectively reviewed, potential costs savings account to 310,997.215 TDN and 857,052.11 TDN in management and maintenance costs, respectively, which is over a half of the total operating cost of 61 oases irrigation schemes in 2018/2019 (Table 4).

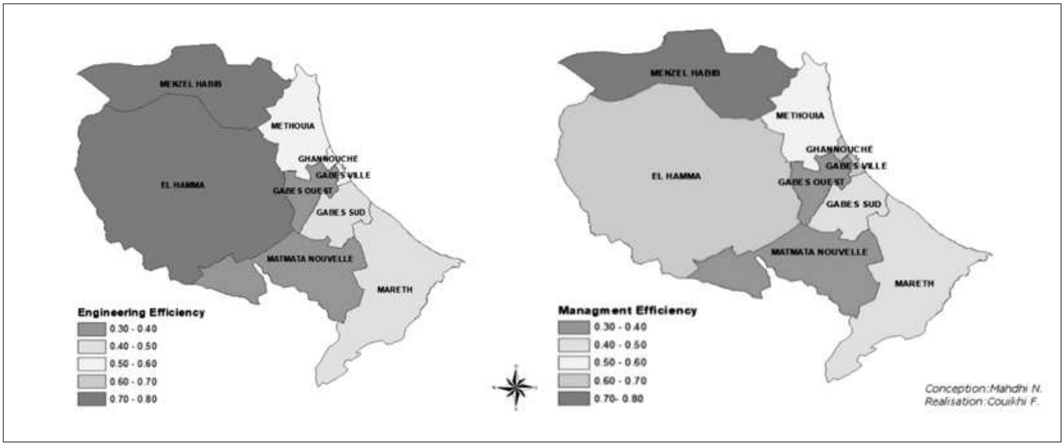
Results also show a great disparity in terms of efficiency among districts (Figure 4). Three (33.33%) districts were found to be technically inefficient (between [30; 40%]), while five of them (55.55%) have achieved scores below

Table 4 - Actual and target values and reduction rates for inputs and outputs by efficiency groups.

Efficiency group	*Input / Output*	*Actual*	*Target*	*Reduction (%)*
0<TE<=0.5	Management costs	18,562.6	6,934.87	62.64
	Maintenance costs	48,254.95	17,318.74	64.10
	Irrigation area (ha)	109.20	109.20	0.00
	Water distributed per irrigated area (m^3/ha)	6,850.22	7,562.57	-10.39
0.5<TE<1	Management costs	12,456.12	8,913.26	28.44
	Maintenance costs	31,064.45	20,193.24	34.99
	Irrigation area (ha)	107.64	107.64	0.00
	Water distributed per irrigated area (m^3/ha)	8,178.41	8,992.40	-9.95
Average	Management costs	15,509.38	7,924.065	48.90
	Maintenance costs	39,659.7	18,755.99	52.7
	Irrigation area (ha)	108.42	108.42	0.00
	Water distributed per irrigated area (m^3/ha)	7,514.315	8,277.485	-10.15

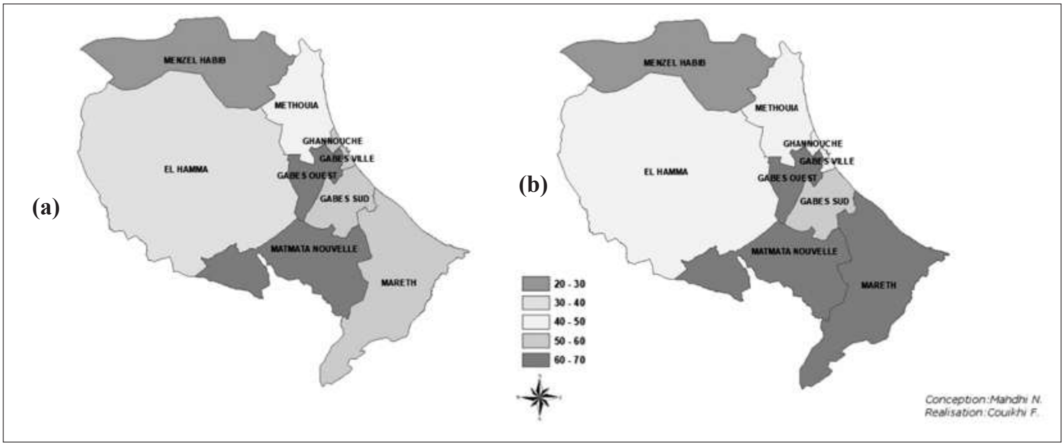
Source: Own elaboration from model results and data survey (2019).

Figure 4 - Engineering and management efficiency by districts.



Source: Own elaboration based on model results (2019).

Figure 5 - Percentage of reduction in inputs by districts: (a) management costs and (b) maintenance costs.



Source: Own elaboration based on model results (2019).

the average in engineering and management efficiency. It is therefore clear that districts with low-efficiency values need to decrease their management and maintenance costs to the level of efficient districts. Figure 5 shows percentages (with respect to current value) by which each district (region) should reduce each one of its inputs in order to become efficient.

3.2. *The determinants of efficiency*

Table 5 reports the estimated coefficients for four separate Tobit regressions. The Tobit regression assumes that the residuals are normally distributed according to Holden (2004). The conditional moment test for normality in censored data (Purmalino *et al.*, 2015) indicated that the normality hypothesis could not be rejected. Furthermore, a log-likelihood test rejected a null hypothesis that all slope parameters were simultaneously nil with statistic tests of 12.14, -16.328, -0.82 and -3.08 for the four regression, and confirmed that all Tobit models were significant. With a pseudo R square ranging from 0.24 to 0.88, the model fits were satisfactory for all regressions.

Table 5 - Factors associated with efficiency scores.

Explanatory variable	*Explained variable*							
	SE		*Pure TE*		*Mg.Efficiency*		*Eg.Efficiency*	
	Estimate	*P-Value*	*Est.*	*P-Val.*	*Est.*	*P-Val.*	*Est.*	*P-Val.*
Tech. char. of the irrig. dist.								
N. of years in function	-0.0012	0.282	-0.0028	0.195	-0.0027*	0.09	-0.003*	0.094
N. of water pumping stations	-0.00004	0.617	-0.0004***	0.001	-0.0003***	0.00	-0.0003***	0.000
Resource size	0.0008***	0.00	0.0017***	0.005	0.0001	0.664	0.0002	0.378
Ratio of water losses	0.041	0.240	-0.003	0.477	-0.0060	0.160	-0.005	0.112
Irrigation ratio	0.0004	0.750	0.0038*	0.101	0.0029*	0.098	0.002	0.172
Administ. and org. charact. of WUA								
Ratio of farmers who are members of WUAs	-0.0002	0.911	0.0004	0.925	0.0015	0.599	0.002	0.393
N. of members in the administration council	- 0.024	0.159	0.049	0.235	0.038	0.164	-0.046*	0.107
Constant	0.694**	0.032	0.784*	0.090	0.487	0.165	0.346	0.306
Σ	0.168	0.022[a]	0.266	0.031[a]	0.214	0.03[a]	0.223	0.032[a]
Pseudo R^2	0.415		0.249		0.88		0.61	
Log-pseudo-likelihood test	-12.14		-16.328		-0.82		-3,08	
Test value CM Normality	$\chi^2 = 34.85$		$\chi^2=43.92$		$\chi^2=53.54$		$\chi^2=44.38$	
N. of observations	**61**		**61**		**61**		**61**	

*Note: *, **, ***= significant at 10,5 and 1% level respectively. [a]For σ the standard error is reported instead of the P-value. Source: Own elaboration from Tobit model results (2019).*

Concerning the individual variables, the results of Tobit models showed consistency. Most of the estimated coefficients of the technical characteristics of the irrigated district were significant, whereas mainly administrative and organizational characteristics of the WUA were not significant in all models. The number of years in functioning, the number of water pumping stations and the irrigation ratio negatively influenced technical efficiency and management and maintenance costs sub-vectors efficiencies, while the other significant variables (the irrigation length of the water carrier, the ratio of water losses) had a positive effect on the efficiency measures.

While looking at the scale efficiency measure, the estimated coefficients of resource size, ratio of water losses, irrigation ratio and the number of members in the administration council were positive, whereas the number of years in functioning, the number of water pumping stations and the ratio of farmers who are members of WUAs were negative. Among these variables, only the estimated coefficient of the length of the irrigation water carrier was significant at a 1% level.

For the pure technical efficiency scores, technical variables are statistically significant. As a matter of fact, we found that the number of water pumping stations and the irrigation ratio have a significant negative effect, whereas resource size has a positive effect on the efficiency measures of WUAs. The other technical characteristics (number of years in functioning, the ratio of water loss) have a negative but not significant effect on the pure technical efficiencies. Table 5 also presents the results for the two Tobit estimates when the dependent variables are management and engineering efficiency scores, respectively. For both regressions, the number of years in functioning and number of water pumping stations have a negative and statistically significant effect at 5% and 1% levels, respectively, whereas the ration of water losses has a positive effect on the efficiency measures. In addition, management efficiency was found to be also negatively affected by the irrigation ratio. Remaining independent variables had no significant effect on both dependent vectors.

4. Discussion

The study used a DEA approach to measure the technical, management and engineering efficiencies for WUAs in an oasis-irrigated region in Southeastern Tunisia. The Sub-vector Data Envelopment Analysis has been used for the first time to assess management and engineering efficiencies that express the performance of a given WUA in terms of allocating expenses for internal management, functioning activities, and maintenance tasks. The major finding shows that 80% of irrigation schemes are not technically efficient and 57.37% of them have technical efficiency scores below the average level of 62.5, compared to an average scale efficiency score of 81.9. Thus, the problem of irrigated WUAs is mostly related to management rather than to the inefficiency scale. Based on the SE scores, the WUAs have used 19.1% extra input because they possess a different scale than the optimum size. This finding confirms the inefficiencies reported by Umetsu *et al.* (2005), Sayin and Yilmaz (2015) in Turkey, Ntantos and Karpouzos (2010) in Greece, Frija *et al.* (2008) in Tunisia. However, Fujiie *et al.* (2005) and Frija *et al.* (2008) found that collective action in local water management is difficult to establish when the size of the association (measured by its service area) is large. In our case, we can conclude that an adjustment of the scale could improve the global efficiency and the use of financial resources in Tunisian WUAs.

The calculated management and engineering sub-vector efficiency show poor performance in terms of allocating expenses for internal management and functioning activities, but also in terms of allocating expenses for maintenance tasks. As a matter of fact, operation and maintenance are among the main WUA expenditures. However, important losses in those financial tasks were assessed in the present study, despite the objective fixed by the government to cover the total maintenance and operation costs.

The low level of sub-vector efficiency of WUAs is explained by major problems caused by the lower irrigation ratios, over-irrigation, insufficient maintenance and repair services, challenges in the collection of water fees, the need for rehabilitation of facilities, inadequacy of new investments, and inability to encourage producers to participate in the management of irrigation systems. Irrigation facilities must be operated efficiently and effectively in order for WUAs providing water distribution services to continue to exist and to carry out their activities successfully.

This is consistent with several reviews on WUAs in the literature that reported the two most prominent criticisms of WUAs to be found are the unrealistic expectations on cost recovery and the inability to promote an inclusive user participation during the implementation of irrigation projects (Aarnoudse *et al.*, 2018).

The result of Tobit models shows that resource size (irrigation network), the age of WUA, the number of pumping stations and the irrigation ratio have a significant impact on efficiency measures. Among these variables, the estimated coefficients of the resource size affected positively scale and pure technical efficiency. Thus, the WUAs with a larger size could lead to a more efficient scale of operation than the smaller size, as measured by the length of their level canals. This is consistent with the argument reported by Bardhan (2000), Frank and Ward (2010) and Zema *et al.* (2018) who confirmed that the adoption of growing size policies allows to obtain economies of scale and better financial and organizational performances, as well as lower costs of the irrigation service for the larger WUAs. Our first field inspections confirm this finding. However, in order to benefit from this greater efficiency and the scale effect, a modernization of irrigation techniques should be encouraged. Other important factors, which had a significant impact on purely technical and sub-vector efficiencies, were the number of years in function and the number of pumping stations managed by a given WUA. The age of a WUA has a negative and highly significant impact. In contrast, older associations are expected to be more stable (Frija *et al.*, 2008; Huang, 2014). Nevertheless, this result can be interpreted in two ways. Over time, irrigation networks get older and the experience of management matters in terms of maintenance. Therefore, their renewal will be more expensive. Huang (2014) reported that maintenance costs increase proportionally with the manager's experience. For this reason, older WUAs require a higher budget especially for maintenance and management tasks, which can influence their global efficiency and lead to resource losses. Therefore, the modernization of irrigation techniques, good network management, and renewal strategies could be a solution. However, in most cases, the WUAs members are not qualified enough to ensure the management and technical supervision: the elaboration of a global optimal management plan will be a difficult task, thus, governmental assistance will be needed. The second explanation of the negative impact of the WUA's age can be reported as a non-social sustainability between the members of the association. According to Meinzen-Dick *et al.* (2002), older organizations seem to be more stable due to the lack of trust and the presence of social conflicts between members of the association. For the Tunisian case, some specific studies (Frija *et al.*, 2017) report the existence of such conflicts and the weak social relationships between farmers and members in the Tunisian WUAs. The number of pumping stations managed in a given WUA has a negative impact too. As a matter of fact, each pump is used by a group of farmers. The effect of the number of users of the irrigation system can be ambiguous. This is probably due to the difficulty in coordinating water deliveries increasing with the group size. These findings validate the early work of Olson (1965) and Weissing and Ostrom (1990) cited in Bardhan (2000), Meinzen-Dick *et al.* (2002) and Wang *et al.* (2010) cited in Zhang *et al.* (2013), which shows that collective action is easier to organize and monitor in smaller groups. They mentioned that a large group size may negatively affect collective management of water and intensify problems of free riding. Zhang *et al.* (2013) indicated that this effect was not significant. According to our first field inspections, the timing of the pumping is always a source of conflict between farmers who want to irrigate at the same time. An increase in the number of pumps and the creation of sub-councils of farmers could be good alternatives to improve the global efficiency of WUAs. Finally, the irrigation ratio had a significant positive impact on pure technical and management efficiencies. This suggests that an improvement of this ratio could lead to greater efficiency. It also has a positive impact even on the scale, and engineering efficiencies. These findings match with the work of Zema *et al.* (2018) in Calabria (Southern Italy). An increase in the irrigation ratio should be one of the main activities to be encouraged by managers to improve the performance of irrigation. Since the number of governing board members affects the scale and engineering efficiency, the reduction in their members would improve the scale efficiency.

5. Concluding remarks and policy implications

This study has carried out a comprehensive analysis of the efficiency of collective irrigation sectors in oases areas, where irrigated agriculture plays an important role in the economic sector and the hydrological risk is pressing. The combined use of DEA and Tobit models seems to be a very useful tool for efficiency assessment and the identification of factors that determine overall management and maintenance efficiencies, as well as scale efficiency of the Tunisian

WUAs. The organizations studied were particularly complex for many reasons. As a matter of fact, multiple objectives and different targets can be pursued, leading to bias in some annual stated inputs, which can be used in the DEA models.

The DEA analysis highlights the fact that management and maintenance tasks are important criteria in determining the WUAs' overall performance and efficiency. DEAs allowed, firstly, the identification of the inefficient WUAs and the performance of the remaining collective organizations (considered efficient) to be employed as reference. It is then clear that districts with low-efficiency values need to decrease their management and maintenance costs to the level of efficient WUAs. Therefore, the modernization of irrigation techniques, good network management and renewal strategies could be a solution. In WUA, irrigation facilities must be operated efficiently and effectively in order for the organizations providing water distribution services to continue to exist and successfully carry out their activities. Aside from a proper planning, design and construction of irrigation networks, efficient operation is crucial. Indeed, the scarcity of resources tend to push WUAs in oases areas to use resources more efficiently, which brings the concept of efficiency to the fore. For these organizations, characterized by a limited funding (i.e., collected water fees), the concept of efficiency is crucial in turning water distribution service expenditures into outputs. The major finding regarding the determinations of WUAs' efficiency concerns the negative effect of the association's age and the pumps' number on its performance. This raises some questions about the sustainability of these WUAs, which should be investigated. Globally, the technical characteristics of the irrigated districts and network have a significant impact on all efficiency measures. However, mainly administrative and organizational characteristics of the WUA were not statistically significant.

The findings provided in this research suggest that more analysis of the Tunisian WUAs should be undertaken in order to clarify some additional aspects of the structure and the functioning of WUAs. For further analysis, a comprehensive assessment of WUAs' management and productivity in oases areas, compared to other regions of Tunisia, may be necessary to understand and predict future scenarios for WUAs.

A comparative context-specific classification of WUAs under specific typologies will certainly help the assessment of different understandings and experiences among water stakeholders and key factors, other than formal organization, in the management of participatory irrigation. It was also important to study the effectiveness and sustainability of water resources for the development and for the ecosystem in the south of Tunis and how WUAs can disseminate the information (or advice) to the public.

Because of lack of available data, environmental factors such as soil quality, gradient, salinity conditions in each WUA were not considered. It may be worthwhile to separate the external environmental factors that may be affecting management practices when a data set is available. The WUAs contribution in improving water efficiency and their wide impact of water use and allocation still need to be further investigated. In view of the future consequences of climate change and water scarcity in the region, the role of WUAs for an efficient management of water resources seems important. Finally, greater reflection is needed to understand the limitations of WUAs and to offer alternative, viable and context-based adapted models.

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How to foster employee satisfaction by means of coaching, motivation, emotional salary and social media skills in the agri-food value chain

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DOI: 10.30682/nm2101c
JEL codes: D92, J24, M52, O15, Q13

Abstract

Most employee satisfaction studies do not consider the current digital transformation of the social world. The aim of this research is to provide insight into employee satisfaction in agribusiness by means of coaching, motivation, emotional salary and social media with a value chain methodology. The model is tested empirically by analysing a survey data set of 381 observations in Spanish agribusiness firms of the agri-food value chain. The results show flexible remunerations of emotional salary are determinants of employee satisfaction. Additionally, motivation is relevant in the production within commercialisation link and coaching in the production within transformation link. Whole-of-chain employees showed the greatest satisfaction with the use of social media in personnel management. Findings also confirmed that employees will stay when a job is satisfying. This study contributes to the literature by investigating the effect of current social and digital business skills on employee satisfaction in the agri-food value chain.

***Keywords**: Agribusiness firms, Value chain methodology, Job satisfaction, Model of employee satisfaction, Turnover.*

1. Background and objective

Employee satisfaction has become a dominant managerial concern in business according to both academics and practitioners because employees are increasingly important for organisational success, growth and competitiveness (Barbosa, 2020; Khan and Aleem, 2014; Saari and Judge, 2004). Employee satisfaction drives productivity because satisfied employees are highly motivated, have good work morale, are more committed to work (Raziq and Maulabakhsh, 2015), are more integrated both internally and with trading partners (Jacobs *et al.*, 2016), work more effectively and efficiently (Eskildsen and Nussler, 2000), enhance business quality (Matzler *et al.*, 2004), improve customer satisfaction and increase business outcomes, including profit (Harter *et al.*, 2002). Nevertheless, employee satisfaction is a complex set of expectations which are the result of both labour market determinants and psychological processes (Matzler *et al.*, 2004) that requires deeper research (Alegre *et al.*, 2016).

Employee satisfaction has been extensively investigated. Locke (1976) noted more than 3,300 articles on the topic in 1976, and for the years 1976 through 2000, Harter *et al.* (2002) found another 7,855 publications. Nevertheless,

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most employee satisfaction studies do not consider the current digital transformation of the social world. The digital transformation of the social world is one of the most discussed issues within business management (Sacolick, 2017). Business management needs to include connections between man and technologies which are largely absent from the employee satisfaction literature. Additionally, social business has not yet been included among the many employee satisfaction factors examined (Kianto *et al.*, 2016). Organisations are social systems where human resources are a crucial factor (Rad and Yarmohammadian, 2006). In this context, the valuation of human capital, the investigation of various combinations of employment modes, and the management of employee relationships are of primary interest (Matzler *et al.*, 2004). Nevertheless, managers usually spend a minimal amount of time on human behaviour, communication, and how to impact employee performance (Rad and Yarmohammadian, 2006). The social business model considers a humanistic business approach that does not follow a purely commercial logic alone and integrates theories of humanistic management (Dierksmeier, 2016). To the best of our knowledge, previous studies provide a partial view of employee satisfaction without taking a global view (Alegre *et al.*, 2016) of the current digital transformation of the social world. This research posits these factors because authors agree that social and digital managerial skills such as coaching, motivation, emotional salary, and social media (SM) can contribute to employee satisfaction (Garcia, 2011). In this sense, it is crucial to know the several social and digital factors influence employee satisfaction from a human resource managerial perspective (Matzler *et al.*, 2004).

Employee satisfaction research has mostly focused on other industries (Raziq and Maulabakhsh, 2015) and has neglected agribusiness. One of the greatest challenges faced by agribusiness in the 21st century is attracting, motivating, and retaining sufficient and qualified labour (Bitsch, 2009; Jankelova *et al.*, 2017). This had led to concerns that labour retention and labour productivity in agribusiness are not at optimum levels, thus resulting in high turnover, depressed profits, and low business wages (Bitsch and Hogberg, 2005). Moreover, given the recent challenges regarding innovation in technology and information systems, global economies, the climate, and changes in demography make agribusiness competitiveness a topic of much interest in both the popular press and academic literature (Bitsch and Hogberg, 2005; Callado and Soares, 2014; Chen *et al.*, 2016). In this line, Mugera (2012) demonstrated that agribusiness competitiveness will mainly be through the adoption and use of new and innovative programs and practices in human resources management (Khan and Aleem, 2014). Jankelova *et al.* (2017) expressed that agribusiness still fails to perceive the importance of human resources management, beyond it being simply a service unit in the organisational structure of the business. They demonstrated that managers in agricultural businesses do not seek to gain a better understanding of the relationship between employee motivation and commitment, and personal and family life. Moreover, Bitsch (2009) demonstrated that many agribusiness managers perceive their personnel management competencies as a weakness and pointed out that the peculiar circumstances of agribusiness require specific skill sets. Therefore, agribusiness firms' success could be achieved through changing management models leading to new workplace relationships focused on human factors and social relations in the organisation (Jankelova *et al.*, 2017) because human resources are one of the crucial strategic assets in agribusiness (Mugera, 2012) and have not received significant attention in the literature.

Therefore, we characterised the employee satisfaction research in agribusiness (Table 1) according the Herzberg's theory that claims that work environment determines job satisfaction in three main areas: the work itself, the responsibility one has in the work and the recognition received from performing the work (Herzberg *et al.*, 1967).

The revision of employee satisfaction in agribusiness shows that most job satisfaction studies in agribusiness firms have focused on job attitude and/or hygiene factors and no previous research has considered digital and humanistic skills such

Table 1 - Revision of previous studies about employee satisfaction in agribusiness.

Author/Type	*Objective*	*Variables**	*Country/ Region*	*Subsector*	*Findings*
Meyerding and Lehberger (2018) *Quantitative*	To analyse gender-specific job satisfaction	Job-hygiene	Germany	Horticulture	No significant differences between gender
Hoque, Rabbany, Anny & Akter (2016) *Quantitative*	To investigate factors affecting job satisfaction of employees agribusiness sector in Bangladesh	Job-attitude and -hygiene	Bangladesh	Agroindustry	Job hygiene factors influence significantly to achieve job satisfaction
Buriro, Tunio, Mumtaz, Mahar & Afzal (2016) *Quantitative*	To determine the most influential factors affecting the job satisfaction and overall satisfaction of employees	Job-attitude and -hygiene	Pakistan/ Sindh	Flour mills	Salary-benefits, healthy working conditions, merit-based fringe benefits, achievements and learning from work determine work satisfaction
Chen, Yueh & Liang (2016) *Quantitative*	To investigate perceptions of farmers' association of online Marketing Service	Job-hygiene	Taiwan	Agricultural	Employees lack of tangibility of service quality, followed by reliability, empathy, responsiveness, and assurance
Callado and Soares (2014) *Quantitative*	To analise the relationships between business performance indicators	Job-hygiene	Brazil/Parana	Agroindustry	Relationship between indicators of profitability, after sales services and employee's satisfaction
Bitsch and Hogberg (2005) *Qualitative*	To analyse job satisfaction of agricultural employees	Job-attitude and -hygiene	USA/ Michigan	Horticulture	Job-attitude is more often job satisfaction and hygiene in the context of dissatisfaction
Ladebo (2005) *Quantitative*	To examine effects of Type A behavioral pattern (TABP) on quit intention's and withdrawal behaviors of employees	Job-attitude	Nigeria/ Southwestern	Agricultural	TABP is positively related to employee loyalty and participation
Bitsch, Bromm & Schalich (2004) *Quantitative*	To explore the potential of flexible arrangements in production enterprises	Job-hygiene	Germany	Horticulture	There is a large potential and demand for benefits change and time arrangements

*Note: *Based on Herzberg theory where Job-attitude means: achievement, recognition, work itself, responsibility and advancement; Job-hygiene means: salary, interpersonal relations, supervision technical, company policy, working recognition, personal life, status, job security (Herzberg et al., 1967).*

coaching, emotional salary and/or SM. We only found Katona-Kovács and Bóta-Horváth (2012) who noted the need to consider coaching in new rural businesses because of their remoteness from markets, isolation, lack of leadership and little access to the value chain.

No previous research considered agribusiness subsectors simultaneously, but rather one at a time. In this line, some authors pointed out that more empirical research and with more representative sampling including several chains embedded in the value chain are needed (Bitsch 2009; Lu and Gursoy, 2013). The value chain should be seen as a system of several interrelated and mutually supportive businesses, and if these are to work effectively together, the employees must be treated as internal customers who need to be continually satisfied (Matzler *et al.*, 2004). The complexity of the agri-food system currently drives managers and academics to conceive the analysis of agribusiness firms based on their performance in the value chain.

To the best of our knowledge no previous research has been conducted on Spanish agribusiness firms despite the fact that recent analysis has shown that country and culture is a strong predictor of employee attitudes and satisfaction (Saari and Judge, 2004). The need to measure, understand and improve employee satisfaction is essential for Spanish agribusiness firms today.

The aim of this research is to provide insight into employee satisfaction in agribusiness firms by means of humanistic and digital managerial skills with a value chain approach.

2. Literature/theory

2.1. *Explanatory variables of agribusiness firms' characteristics*

Meyerding and Lehberger (2018) stated that agribusiness can be divided into many subsectors, where very different working conditions prevail to determine employee satisfaction. Platis and Zoulias (2017) demonstrated the impact of organisation style on employee satisfaction, while Huang *et al.* (2015) provided evidence that family firms exhibit a human capital enhancing culture that improves employee satisfaction. Moreover, Bitsch (2009) stated that issues and practices developed for large corporations do not always scale down well to smaller businesses. Therefore, our model of employee satisfaction considered business variables such as number of employees, year of foundation, subsector, link of the value chain, existence of a webpage, SM and key performance indicators. Then, the first of the hypotheses that this study seeks to test is as follows:

H1: The agribusiness firm characteristics determine employee satisfaction using coaching, motivation, emotional salary and social media skills.

2.2. *Explanatory variables of employee characteristics*

The literature has largely analysed the effects of employees' characteristics on job satisfaction (Judge *et al.*, 2002). Lu and Gursoy (2013) demonstrated generational differences between baby boomers and millennials in determining employee satisfaction and exhaustion. Wheatley (2017) demonstrated the impact of gender on employee satisfaction, while Meyerding and Lehberger (2018) found no significant gender differences for job satisfaction in German horticulturists. Therefore, our model of employee satisfaction considered employee characteristics such as gender, age or position. Then, the second of the hypotheses that this study seeks to test is as follows:

H_2: The employee characteristics are determinant in satisfaction using coaching, motivation, emotional salary and social media skills.

2.3. *Satisfaction and willingness to leave*

The literature has argued that an individual will stay when a job is satisfying but that they will leave a dissatisfying job (Judge *et al.*, 2001; Ladebo, 2005; Lu and Gursoy, 2013) either to a new type of job in the same business, the same job in a different business or a different job in a different business (Fields *et al.*, 2005). Gollin *et al.* (2014) pointed out the strong incentives for moving out of agriculture and into other economic activities. Researchers have found that job satisfaction is significant with respect to turnover (Harter *et al.*, 2002) and absenteeism (Lee and Liu, 2007), and managers strive to prevent turnover intention as employees' actual turnover generates extensive costs for both the individual and the organisation (Karatepe and Ngeche, 2012). Therefore, retention and turnover of staff, particularly highly skilled personnel, are important for managers, while Babalola (2016) indicated that an employee will continue on a job as long as it continues to be rewarding. Thus, the research model considered a variable named *willingness to leave* (Table 2). Then, the third hypothesis that this study seeks to test is as follows:

H_3: Employees will stay when a job is satisfying.

2.4. *Humanistic and digital managerial skills variables*

Authors have demonstrated both qualitatively and quantitatively the importance of a supervisor and their influence over the level of engagement of employees and their satisfaction (Alegre *et al.*, 2016; Judge *et al.*, 2001; Kianto *et al.*, 2016). The use of leadership behaviours is positively correlated with employee satisfaction (Babalola, 2016; Belias *et al.*, 2015; Rad and Yarmohammadian, 2006), and Bitsch and Hogberg (2005) found that a supervisor who is understanding and flexible, who has a sense of humor, who shows recognition and gives constructive feedback and who builds loyalty in horticulture employees is more likely to interact with employees on professional, emotional, and spiritual levels (Babalola, 2016; Tang *et al.*, 2014; Vidal-Salazar *et al.*, 2015). In the case of agricultural businesses, Jankelova *et al.* (2017) pointed out that humanistic managers need to improve employee loyalty and engagement, help employees satisfy their own needs, listen to employees and find solutions, react to their problems, mold their behaviour in order to promote organisational changes and support employees to meet their own needs (Wang, 2013). Finally, Kianto *et al.* (2016) demonstrated that knowledge-sharing activities, including informal communication, brainstorming sessions, mentoring and coaching, can be a way to nurture job satisfaction. Therefore, we created in our model of employee satisfaction a variable named *coaching* (Table 2).

The literature on job satisfaction has broadly linked employee motivation to satisfaction (Khan and Aleem, 2014). Kianto *et al.* (2016) pointed out that employee motivation is connected especially to social belonging, self-esteem and self-realisation. Motivation is one of the hardest and most important tasks of running a business, as it has significant impact on employee performance (Belias *et al.*, 2015). Rad and Yarmohammadian (2006) stated that some job motivating skills are related to good pay, good working conditions (Belias *et al.*, 2015), involvement in reward systems such as recognition and incentives (Bitsch and Hogberg, 2005), promotion (Khan and Aleem, 2014) and training plans (Matzler *et al.*, 2004). Babalola (2016) suggests that employees are more satisfied with their jobs when they are adequately recognised for a job well done. Accordingly, we created in our model of employee satisfaction a variable named *motivation* (Table 2).

Allen *et al.* (2003) underlined the importance of company support of employee work-family balance (Tang *et al.*, 2014) and flexible working arrangements (Wheatley, 2017) for employee satisfaction. In this sense, businesses are looking for flexible remuneration systems (Vidal-Salazar *et al.*, 2015), such as highly personalised and adjustable indirect remuneration systems, flexible benefit plans which are designed to improve employees' pay efficiency including health insurance, bonuses system, etc., along with better time arrangements (Bitsch *et al.*, 2004; Perez-Perez *et al.*, 2017) with flexible schedules, telecommuting, conciliation among work time, leisure time and familial time, personal and professional promotion, etc. Therefore, we created a variable including flexible remunerations of emotional salary named *emotional salary* (Table 2).

Stamolampros *et al.* (2019) confirmed the effect of SM on employee satisfaction. SM can contribute to developing personal abilities and leadership (Garcia, 2011), improving employee cooperation and communication (Felix *et al.*, 2017), enhancing informal relationships, identifying mentors, facilitating homeworking and

Table 2 - Variables description to approach humanistic business management in the digital era.

Variable	*Definition*
Willingness to leave	The employee willing to leave the job in the next 6 months.
Coaching	There is a supervisor or coach that guides, motives, advices and trains the employee.
Motivation	There are incentives, recognitions, training plans or other forms of motivation.
Emotional salary	There are flexible schedules, telecommuting, health insurance, bonuses system, conciliation among work time, leisure time and familiar time, personal and professional promotion.
Social Media personnel	The firm uses new technologies for internal communications, to involve the employees in the business decisions and feedback.

developing social activities (Garcia, 2011). Internal communication has a significant positive effect on employee satisfaction and that internal communication and employee satisfaction significantly influence internal integration (Jacobs *et al.*, 2016). According to Garcia (2011) internal integration generates business loyalty and commitment. Then, in the research model we considered a *social media personnel* variable.

Thus, the fourth hypothesis that this study seeks to test is as follows:

H4: Coaching, motivation, emotional salary and social media determine employee satisfaction.

Finally, considering the complexity of the agri-food system and the need to analyse agribusiness firms embedded in the value chain, the fifth hypothesis that this study seeks to test is as follows:

H5: The link in the value chain determines employee satisfaction using coaching, motivation, emotional salary and social media skills. Figure 1 shows the research method.

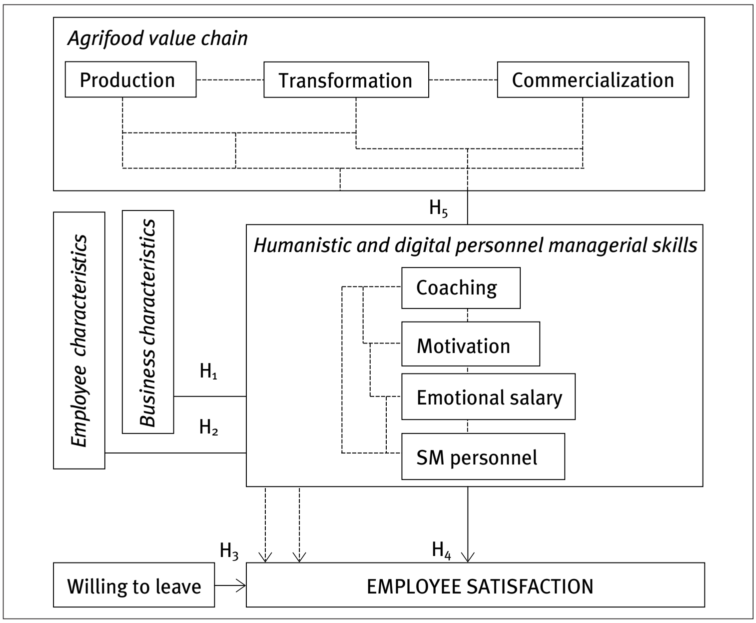

Figure 1 - Research model. Figure 1 represents the research model that considers business characteristics (H_1), employee characteristics (H_2), employee willingness to leave a job (H_3), humanistic and digital skills (H_4) and the value chain approach (H_5).

3. Methodology

3.1. *Sample and data collection*

To test the hypotheses of our research model, data were gathered using Spanish agribusiness firms. Firstly, a questionnaire was prepared according to previous research (Bowling and Hammon, 2008; García and Forero, 2014; Huilcapi *et al.*, 2017; Randstad, 2017). Before testing, as a means of exploring, we conducted surveys of a non-probabilistic sample of 100 Spanish agribusiness firms in order to refine and pretest the questionnaire that had been designed. All the firms were first contacted by mail (followed up once or twice a week) and later by telephone in order to fill the required sample. A sample of 381 agribusiness Spanish firms in the agri-food value chain was analysed (Table 3) from a total of 43,624 agribusiness firms in Spain at the time of the study (MAPAMA, 2018), of which 24,410 were agri-food industries, 15,355 agrarian firms and 3,859 wineries. Businesses were screened against inclusion criteria for being Spanish agribusiness firms belonging to the agri-food, agrarian or wine subsector and performing in the value chain. Two criteria sample groups were included to examine potential cross-subsectors and value chain link differences. The agribusiness firms of the sample were selected following a stratified sampling procedure by subsector, size, and year of foundation from the total population of official records (CES, 2016; INE, 2017; MAPAMA, 2018). Due to the stratified sampling procedure, the data showed a representative distribution of Spanish agribusiness firms' characteristics (Table 3). The sample size (381) yielded a 95.0% confidence interval with a 5.0% predicted margin of error. Finally, the surveys were selected from two Spanish firms' directories by size, year of foundation and subsector: i) agri-food and wine (Expansion, 2020a) and ii) agrarian (Expansion, 2020b).

The final version of the questionnaire (Table 4) was sent to agribusiness firms using the Jotform digital tool and after follow-up by telephone, we obtained the 381 complete questionnaires. Some firms refused to participate because, despite our guarantee of total confidentiality, they did not wish to disclose any information concerning this type of management or because employees were too busy to comply with our request. The questionnaire also inquired about the respondent's demographics and agribusiness characteristics.

Table 3 - Sample characteristics.

Subsector	*N Spain*	*% Spain*	*N Sample (381)*
Agri-food	24410	55.96%	214
Agrarian	15355	35.19%	134
Wine	3859	8.85%	33
Number of employees			
1 to 9		90.30%	344
10 to 49		8.00%	30
50 to 199		1.30%	5
≥200		0.40%	2
Year of foundation			
Before 1998		30.50%	116
1998-2015		53.10%	202
After 2015		16.40%	63

Sources: INE, 2017; CES, 2016; MAPAMA, 2018.

Table 4 - Employee and the agribusiness characteristics in the questionnaire.

Characteristic	*Description*	*Variable*	*Scale*	*Type of variable*
Agribusiness	Type of activity	Activity	Agrarian Agri-food Wine	Multistate Qualitative No logic sequence
	Location	Location	Province	Multistate Qualitative No logic sequence
	Year of foundation	Year	Year	Qualitative Logic sequence
	Number employees	Employees	Number	Quantitative
	Link value chain	Link	Production Transformation Comercialization	Multistate Qualitative No logic sequence
	Webpage	Web	Yes No	Dichotomous
	Social media	SM	Yes No	Dichotomous
	Social media KPI	Number followers	Facebook Twitter Instagram	Quantitative
Employee	Position	Position	Position	Multistate Qualitative No logic sequence
	Age	Age	Age	Quantitative
	Gender	Gender	Female Male	Dichotomous
	Job satisfaction	Satisfaction	Yes No	Dichotomous

3.2. *Data analysis*

The two-way dependence between employee satisfaction and the explanatory variables was calculated using a Pearson's Chi-square ($\chi^2_{.94}$) test, because the null hypothesis of normality was rejected through the Kolmogorov-Smirnov test.

A correlation matrix was constructed to test possible multicollinearity among variables. Pearson's correlation coefficient was used, and high correlations were considered if their values were greater than 0.800.

Then, binary logistic regression was used to predict the odds of being satisfied based on the values of the predictors. Regression coefficients were estimated using maximum likelihood estimation and were presented with Wald χ^2-statistics and as odds ratios, by using the Wald forward stepwise method. The models revealed the most important predictor/s of employee satisfaction within the possibility of classifying the likelihood that a respondent is (or not) satisfied with his/her job.

4. Results and discussion

Regarding the sample profile, the participants' age ranges were as follow: < 20, 0.5%; 21-30, 24.4%; 31-40, 34.1%; 41-50, 29.7%; 51-60, 11.3% and > 61, 1.3%. Referring to their position in the business at which they were currently working, it was found that the 34.9% were administrative staff or in sales, 31.8% were supervisors or managers, 18.9% were operators and 14.4% were in executive positions or were owners.

69.3% of agribusiness firms had a website. However, only 20.2% had Instagram, 24.1% Twitter and 54.9% Facebook, from which a low number of followers was observed (from 0 to 100 followers for 80.8% of firms on Instagram, for 82.4% of the firms on Twitter and for 54.3% of the firms on Facebook). This result is in line with the results from Pwc (2018) study which demonstrated main barriers for Spanish firms digitalisation are, the lack of digital culture and knowledge (76%), of leadership spirit (64%), the ignorance of the benefits of digitalisation for the firms (56%), the high cost of digitalisation (28%), the lack of collaboration (24%) and the scarce of talent initiatives (20%).

50.4% of employees with a coach expressed that it is very helpful in their workdays for individual work, teamwork, and to achieve business objectives. The 49.6% of other employees without coaching declared that they were not sure about the function of a coach. 55.1% said that they were motivated due to the agribusiness firm's motivation. 81.6% stated that they had at least two of the flexible paybacks of emotional salary and expressed being satisfied with emotional salary and that they would recommend it. Regarding the use of SM in the internal management of the firms (personnel, processes, etc.), 83.5% declared that the firm did not use SM for this purpose. 86.9% of employees expressed that they were unwilling to leave their job.

4.1. *Agribusiness subsectors*

In the agrarian, wine and agri-food subsectors it was significant and very likely that satisfied employees do not leave their job (*P* = 0.000; 0.007 and 0.000 respectively) (c.t.r.= 5.9; 2.7 and 6.2). This result is in line with previous studies demonstrating that turnover is negatively associated with employee satisfaction (Judge *et al.*, 2001; Ladebo, 2005; Lu and Gursoy, 2013). It was significant likely that employee satisfaction in the agricultural sector is related to motivational tools (*P* = 0.028) (c.t.r. = 2.2), and emotional salary (*P* = 0.000) (c.t.r. =6.3). This result is in line with the results from Bitsch's (2009) study which demonstrated that agricultural employees' job satisfaction and retention can be increased with inexpensive measures, such as feedback and appreciation.

For the wine subsector, it is significant and very likely that employee satisfaction is related to emotional salary (*P* = 0.038) (c.t.r. = 2.1). As for the agri-food subsector, it is significant and very likely that employee satisfaction is related to coaching (*P* = 0.003) (c.t.r. = 3.0) and emotional salary (*P* = 0.000) (c.t.r. = 6.4). These re-

Table 5 - Significant relationship among humanistic digital management skills and employee satisfaction by agribusiness subsectors.

Significant humanistic and digital managerial tools		*Satisfaction*	*P*
Agrarian			
Motivation	Frecuency (%)	55.22	0.028
	c.t.r.	2.2	
Emotional salary	Frecuency (%)	75.37	0.000
	c.t.r.	6.3	
Willingness to leave	Frecuency (%)	81.34	0.000
	c.t.r.	5.9	
Wine			
Emotional salary	Frecuency (%)	87.88	0.038
	c.t.r.	2.1	
Willingness to leave	Frecuency (%)	90.91	0.070
	c.t.r.	2.7	
Agri-food			
Coaching	Frecuency (%)	54.21	0.003
	c.t.r.	3.0	
Emotional salary	Frecuency (%)	78.04	0.000
	c.t.r.	6.4	
Willingness to leave	Frecuency (%)	80.37	0.000
	c.t.r.	6.2	

sults are in consonance with Kianto *et al.* (2016) who demonstrated that job satisfaction differs as a function of sector characteristics and Corstjens and Umblijs (2012) who proved that the subsector influences employee satisfaction. The results can be explained due to the different working conditions of agribusiness subsectors, as stated by Meyerding and Lehberger (2018). Harter *et al.* (2002) also explained that subsector firms differ in how they encourage employee satisfaction and engagement initiatives, and Mugera (2012) pointed out that heterogeneity exists also because of the different firms' organisational cultures, kinship and friendship ties, resource endowments, and human resources practices. From these results, agribusiness firms should learn about the management talent and practices that drive business outcomes if they have studied their own business characteristics.

Table 5 shows that for agribusiness subsectors the first of the hypotheses that the research study sought to test have been confirmed: H_1: The agribusiness characteristics determine employee satisfaction using coaching, motivation, emotional salary and social media skills.

4.2. *Employee characteristics*

As expressed by employees aged 21-30 and 31-40 years, it was significant and very likely that job satisfaction is related to emotional salary (*P* = 0.000) (c.t.r. = 6.6 and 4.9 respectively). As expressed by employees aged 41-50 years, it was significant and very likely that employee satisfaction is related to coaching (*P* = 0.000) (c.t.r. = 2.2) and emotional salary (*P* = 0.000) (c.t.r. = 3.6). This result is in consonance with that of Alegre *et al.* (2016) who demonstrated that a combination of coaching support and greater identification with the organisational strategy of senior employees led to job satisfaction.

Many authors have demonstrated that the generational cohort to which employees belong is likely to influence employees' workplace attitudes, their satisfaction, and turnover intention (Belias *et al.*, 2015; Rad and Yarmohammadian, 2006). This result shows that managers need to use the proper mix of humanistic and digital managerial skills to lead employees from different generations. Younger employees appreciated emotional salary due to being at an age at which employees seek out fascinating projects from which they can learn, progress and be recognised in a good job environment (Salahuddin, 2011). For those aged 41-50, coaching was significant. For these employees, the workplace was of greater importance, and they considered their job as more central to their lives than younger generations. In this stage, employees might strive to maintain their status at work, and hold onto their positions by updating and recycling

Table 6 - Significant relationship among humanistic and digital managerial skills and satisfaction by employee's age.

Age	*Variable*		*Satisfaction*	*P*
21-30	Emotional salary	Frecuency (%)	73.12	0.000
		c.t.r.	6.6	
	Willingness to leave	Frecuency (%)	67.67	0.000
		c.t.r.	4.2	
31-40	Emotional salary	Frecuency (%)	79.20	0.000
		c.t.r.	4.9	
	Willingness to leave	Frecuency (%)	84.00	0.000
		c.t.r.	4.5	
41-50	Coaching	Frecuency (%)	42.48	0.026
		c.t.r.	2.2	
	Emotional salary	Frecuency (%)	82.30	0.000
		c.t.r.	3.6	
	Willingness to leave	Frecuency (%)	91.15	0.000
		c.t.r.	7.3	

Table 7 – Pearson's bivariate correlation between independent variables (N=381).

	Subsector	*Location*	*Year of foundation*	*Number of employees*	*Link value chain*	*Position*	*Age*	*Gender*	*Motivation*	*Coaching*	*Emotional salary*	*Willingness to leave*	*SM personnel*
Subsector	1												
Location	0.331**	1											
Year of foundation	0.332**	0.308**	1										
Number of employees	-0.387**	-0.175**	-0.209**	1									
Link value chain	0.136**	0.082	0.042	-0.161**	1								
Position	0.377**	0.203**	0.287**	-0.253**	-0.043	1							
Age	0.007	-0.081	-0.156**	-0.007	-0.061	0.300**	1						
Gender	0.087	0.092	0.025	-0.119*	0.063	0.057	0.011	1					
Motivation	-0.063	0.038	0.025	0.087	-0.055	-0.015	-0.106*	-0.018	1				
Coaching	0.173**	0.211**	0.271**	-0.132**	0.029	-0.039	-0.175**	0.050	0.192**	1			
Emotional salary	0.056	0.023	0.073	0.024	-0.048	0.137**	0.077	0.013	0.062	0.166**	1		
Willingness to leave	0.013	0.091	-0.070	0.076	0.034	-0.154**	-0.216**	-0.017	-0.024	0.044	-0.317**	1	
SM personnel	0.066	-0.019	-0.002	-0.028	0.054	0.035	-0.051	0.022	0.118*	0.074	0.047	-0.027	1

*Note: ** $p < 0.01$, * $p < 0.05$.*

with a coach (Lu and Gursoy, 2013; Rad and Yarmohammadian, 2006).

For all age ranges, it is likely that employees who are satisfied are not willing to leave their job ($P = 0.000$) (c.t.r. = 4.2; 4.5 and 7.3 respectively) (Table 6).

Table 6 has confirmed for the employee age the second of the hypotheses that the research study sought to test: H_2: Employee age may determine employee satisfaction using coaching, motivation, emotional salary and social media skills.

4.3. *Determinant factors in employee satisfaction*

Multicollinearity was not a major issue in the model as is shown in Table 7.

In Table 8, the regression coefficients with their corresponding standard errors (SE), the value of the Wald statistic to evaluate the null hypothesis ($\beta_i = 0$), associated statistical significances and value of the OR (Exp (β)) and goodness of fit statistics are presented.

Table 8 - Employee satisfaction model for business and employee characteristics, coaching, motivation, emotional salary and social media using coefficient estimates and diagnostics from binary logistic regression and Wald forward stepwise method.

	β	*SE*	*Wald*	*gl*	*Sig.*	*Exp(β)*
Emotional salary	2.456	0.396	38.410	1	0.000	11.654
Willingness to leave	-2.278	0.417	29.834	1	0.000	0.102
Constant	1.050	0.311	11.430	1	0.001	2.858

Goodness-of-fit statistics of the model associated with employee satisfaction: -2Log likelihood statistic=180.377; Nagelkerke R^2= 0.433.

The regression equation shows that emotional salary and willingness to leave are determinant factors in agribusiness employee satisfaction. This result is in consonance with that of Twenge *et al.* (2010) who demonstrated that employees valued extrinsic rewards, flexible work hours, an informal work environment and work-life balance (Tang *et al.*, 2014) as being relevant for job satisfaction. Moreover, Rad and Yarmohammadian (2006) demonstrated that managers could make effective efforts in emotional salary to improve employee morale once employees have covered their primary job needs, while Matzler *et al.* (2004) proved fairness in remuneration is highly significant in employee satisfaction.

The logistic regression equation is constructed as follows:

Y= 1.050 + 2.456*Emotional Salary – 2.278*Willingness to leave.

This logistic equation allows for predicting the likelihood of the satisfaction or non-satisfaction of an employee. The equation explains that the greater the flexible payback of emotional salary is, the greater the likelihood of employee satisfaction. Moreover, it demonstrates that employee satisfaction is negatively associated with a willingness to leave the job.

Y = Satisfaction	X_1 = Emotional Salary (1= Yes, 0 =No).
β_0 = 1.050	β_2 = -2.278
β_1 = 2.456	X_2 = Willingness to leave (1= Yes, 0 =No)

The likelihood of the model predicting that an agribusiness firm employee is satisfied with emotional salary and unwilling to leave the job is 97.1% for a given likelihood > 50%.

$$P = \frac{1}{1+e^{-y}} = \frac{1}{1+e^{-[1.050+2.456(1)-2.278(0)]}} = 0.971$$

The likelihood of the model predicting that agribusiness firm employee is satisfied with emotional salary and willing to leave the job is 77.3% for a given likelihood > 50%.

$$P = \frac{1}{1+e^{-y}} = \frac{1}{1+e^{-[1.050+2.456(1)-2.278(1)]}} = 0.773$$

The likelihood of the model predicting that an employee is satisfied in a firm without emotional salary and is unwilling to leave the job is of 97.1% for a given likelihood > 50%.

$$P = \frac{1}{1+e^{-y}} = \frac{1}{1+e^{-[1.050+2.456(0)-2.278(0)]}} = 0.971$$

The likelihood of the model predicting that an employee is satisfied in a firm without emotional salary and is willing to leave the job is of 22.7% for a given likelihood > 50%. In this case, the predictive ability of the model is compromised.

$$P = \frac{1}{1+\mathrm{e}^{-y}} = \frac{1}{1+\mathrm{e}^{-[1.050+2.456(0)-2.278(1)]}} = 0.227$$

From the data obtained in the model and for a risk α = 0.05, we can conclude that for a total of 381 employees from agribusiness firms, 353 were “satisfied or not satisfied”, or, in other words, 92.7% have been correctly classified according to job satisfaction.

To assess the predictive capacity of the model, sensitivity and specificity values were calculated. It is verified that the model has a high specificity (98.8%) and a low sensitivity (46.7%) so that the model adequately classifies employees as “satisfied” and poorly classifies them as “not satisfied”, which may be related to the distribution of the sample for this variable.

Taking into account the variables of the model as expressed by the 381 employees of the agribusiness firms, 88.2% are satisfied and 11.8% are not satisfied. This is broken down as follows:

- Of the 75.1% of agribusiness firms with emotional salary (1) and employees unwilling to leave (0), 96.5% are job satisfied and 3.5% are unsatisfied.
- Of the 6.6% of agribusiness firms with emotional salary (1) and employees willing to leave (1), 84% are job satisfied and 16% are unsatisfied.
- Of the 11.8% of agribusiness firms with no emotional salary (0) and employees unwilling to leave (0), 77.8% are job satisfied and 22.2% are unsatisfied.
- Of the 6.6% of companies with no emotional salary (0) and employees willing to leave (1), 16% are job satisfied and 84% are unsatisfied.

The model of employee satisfaction in Table 8 has confirmed the third and the fourth hypotheses that the research study sought to test: H_3: Employees will stay when a job is satisfying and H_4: Emotional salary determines employee satisfaction.

It is highly recommended that agribusiness firms' managers should integrate emotional salary into a humanistic and digital management system to foster employee satisfaction. More information about humanistic and digital management may help agribusiness firms' managers understand more fully the impact of their managerial styles on their employees. It is concluded that agribusiness firms' managers should choose the best humanistic and digital managerial style according to their business culture and employees' characteristics. In this process, separate ownership from management may be recommended (Barbosa, 2020).

4.4. *Employee satisfaction and the agri-food value chain*

Results show that emotional salary is the factor most related to employee satisfaction for all the links of the agri-food value chain (Table 9).

In the commercialisation link, it is significant the emotional salary (P = 0.005) (c.t.r. = 2.8) because Rad and Yarmohammadian (2006) demonstrated that recognition and respect are very important, especially for employees who are in direct contact with clients (Table 10).

In the production within transformation link, emotional salary is the factor most related to employee satisfaction (P = 0.001) (c.t.r. = 3.5). This result might be explained by the peak times of work in production and transformation, for instance during harvest, that might recommend flexible remuneration systems (Vidal-Salazar *et al.*, 2015) such end of season bonuses, along with better time arrangements (Bitsch *et al.*, 2004; Perez-Perez *et al.*, 2017).

In the production within commercialisation link, it is significant that the combination of motivation (P = 0.005) (c.t.r. = 2.8) and emotional salary (P = 0.005) (c.t.r. = 2.8) is related to employee satisfaction. This result might be explained by the peculiar circumstances of the production employees who lack marketing abilities (Katona-Kovács and Bóta-Horváth, 2012). Remoteness from markets and little access to the value chain (Mugera, 2012) require extra motivation on the part of production employees to dare commercialisation. Additionally, Bitsch *et al.* (2004) stated that motivation and patience is required more in retailing. Employees in production within commercialisation can benefit from motivation and emotional salary practices that enhance and meet customer expectations (Saari and Judge, 2004).

In the transformation within commercialization link, employee satisfaction is related to coaching (P = 0.001) (c.t.r. = 3.3) and emotional salary (P = 0.000) (c.t.r. = 6.5). This result can be explained by the complexity of the transformation processes that can require more guidance or coaching for employee satisfaction than less complex jobs (Saari and Judge, 2004).

Table 9 - Employee satisfaction on coaching, motivation, emotional salary and social media personnel in the value chain.

Variable						**Value chain link (%)*						
Dependent	Determinants		Others			1	2	3	1,2	1,3	2,3	1,2,3
Satisfaction	Willingness to leave	Emotional salary	Motivation	Coaching	SM personnel							
Yes	No	Yes	No	No	No	42.9	42.9	36.4	39.1	35.7	35.2	37.6
Yes	No	Yes	Yes	No	No	21.4	20.0	23.3	21.7	32.1	20.1	19.7
Yes	No	Yes	No	Yes	No	14.3	20.0	17.8	21.7	10.7	23.4	17.0
Yes	No	Yes	No	No	Yes	7.1	5.7	5.4	0.0	7.1	3.9	9.6
Yes	No	Yes	Yes	Yes	No	7.1	8.6	13.2	17.4	10.7	15.5	11.5
Yes	No	Yes	Yes	Yes	Yes	7.1	2.9	3.9	0.0	3.6	2.0	4.6

*Note: *Value chain link: Production (1), Transformation (2), Commercialisation (3).*

Table 10 - Significant relationship among links of the agribusiness value chain and humanistic, digital management skills and satisfaction.

Value chain link	*Variable*		*Satisfaction*	*P*
Commercialisation	Emotional salary	Frecuency (%)	83.87	0.001
		c.t.r.	3.3	
	Willingness to leave	Frecuency (%)	88.71	0.050
		c.t.r.	2.0	
Production & Transformation	Emotional salary	Frecuency (%)	75.00	0.001
		c.t.r.	3.5	
Production & Commercialisation	Motivation	Frecuency (%)	76.92	0.005
		c.t.r.	2.8	
	Emotional salary	Frecuency (%)	76.92	0.005
		c.t.r.	2.8	
	Willingness to leave	Frecuency (%)	76.92	0.005
		c.t.r.	2.8	
Production, Transformation & Commercialisation	SM personnel	Frecuency (%)	25.00	0.052
		c.t.r.	3.1	
	Emotional salary	Frecuency (%)	75.63	0.000
		c.t.r.	3.6	
	Willingness to leave	Frecuency (%)	81.51	0.000
		c.t.r.	3.3	

In the whole-of-chain link, it is significant that the combination of SM personnel (P = 0.052) (c.t.r. = 3.1) and emotional salary (P = 0.000) (c.t.r. = 3.6) is related to employee satisfaction. This result might be explained by the continuous need for communication for establishing performance in the whole-of-chain link. This result is in line with that of Hadley *et al.* (2002) who proved that communication problems in agri-food value chain persist despite the fact that internal communications have a significant positive effect on employee satisfaction. Moreover, Jacobs *et al.* (2016) proved that internal communications and job satisfaction might contribute to internal and external employee integration which could enhance the performance of the whole value chain. Nevertheless, White *et al.* (2017) analysed the use of SM, and even when they found it to be positive for agribusiness, they found that agribusiness leaves the potential of SM in business management unused. The results confirm that SM in personnel management for agribusinesses is still in its early stages, and the interconnectivity and complexity of SM platforms can be obstacles to strategic personnel management activities over SM, thereby rendering this technology extremely difficult (Felix *et al.*, 2017).

Tables 9 and 10 show that the fifth hypothesis that the research study sought to test has been confirmed: H_5: The link in the value chain determine employee satisfaction using coaching, motivation, emotional salary and social media skills.

5. Conclusion

The aim of this research was to provide insight into employee satisfaction in agribusiness firms by means of coaching, motivation, emotional salary and social media skills with a value chain approach. The results aim to integrate humanistic and digital skills into agribusiness' daily working routines, and in doing so, foster employee satisfaction. The results of this study illustrate that humanistic managerial skills such as flexible remunerations of emotional salary have a positive impact on agribusiness firms' employee satisfaction. It should therefore encourage agribusiness managers to implement humanistic and digital managerial skills in their firms in order to improve well-being at work, employee performance, including competitiveness, and to retain employees because findings also confirmed that agribusiness firm employees will stay when a job is satisfying. In addition, the results demonstrate that different employee groups and links in the value chain benefit from different kinds of humanistic and digital managerial skills. The results indicate that managers should develop proper management and leadership strategies to lead employees from different groups and positions in the value chain. For employees to be effective, managers should consider distinct work values for different generations. Managers should develop an appropriate incentive structure for employees from each generation. This might help improve employee loyalty and satisfaction and lower turnover in agribusiness firms' employees. Employees in commercialisation link can benefit from emotional salary practices such as sales incentives and flexible schedules that enhance and meet customer expectations. The employees in production within transformation link can benefit from flexible remuneration systems such as end of season bonuses, along with better time arrangements. Motivation can benefit employees performing production within commercialisation due to the lack of marketing abilities of the production employees that require extra motivation to dare commercialisation. Coaching can benefit transformation within commercialization link because the complexity of the transformation processes requires more guidance. Employees in the whole-of-chain presented the greatest job satisfaction with the use of social media in personnel management due to the continuous need for communication for establishing performance in the whole-of-chain. Finally, job satisfaction can contribute in agribusiness firms to internal and external employee integration which could enhance the performance of the whole value chain. Moreover, humanistic and digital management can gain a strategic character that improves competitiveness and is a creator of added value for the organisation, its employees, as well as clients, and which can improve the performance of the whole agri-food value chain. This study contributes to the employee satisfaction literature by investigating the effect of the current social and digital businesses managerial skills and advancing the discipline of agribusiness management.

5.1. Practical implications

The results of this research also have practical implications for managers because they may provide them with a more holistic understanding of employee satisfaction in the current social and digital business world. How can agribusiness firms attract, motivate, retain and satisfy their employees? This question is relevant for practice. These research findings should be taken into consideration by managers to foster and promote increased employee satisfaction, leading to higher productivity and general well-being. In this sense, lessons can be extracted from this research and offer guidance for both agribusiness management practice and future research. Employers and managers can use the results to tailor their management practices to specific employee groups and performance in the value chain, thereby increasing retention and productivity. Employees will benefit from improved management practices in terms of higher job satisfaction and increased ability to develop their full potential. Agribusiness firms' managers should be educated to choose the proper skills, either being trained and advised by experts in humanistic and digital managerial skills or sub-contracting the humanistic and digital management of the firm. After that, they should apply the proper skills to foster employee satisfaction. The results of such studies can be very helpful for developing a new model of management with the implementation of new humanistic and digital skills that can be executed easily and successfully. Aligning the personal needs of the employees with those of the organisation can be helpful in the development of loyalty and retention of employees.

5.2. *Future research lines*

There is scope for further research regarding the generalisation of the findings in connection with the majority of agribusiness firms. The future direction of employee satisfaction research will be able to better understand the interplay between the person and the situation and the various internal and external factors that influence employee attitudes for ages and subsectors. Other sociodemographic variables common to the agribusiness sector, such as race, ethnicity, or culture of employees, might play critical roles in predicting significant differences in job satisfaction and work values, and this requires future research. This paper assumes that there is a connection between satisfaction and performance, although this assumption has not yet been tested empirically. By demonstrating that the benefits of the use of coaching, motivation, emotional salary and SM to foster employee satisfaction differ as a function of the link of the value chain, the paper supports moving employee satisfaction research to the next stage at which the impact of humanistic and digital practices can be explored as a contingent and contextual issue, taking into account the requirements and characteristics of the various types of tasks conducted in a business. In this line, the impact of COVID-19 in the labour market, in the most vulnerable segments of the working population, in the use of personnel SM, in telecommuting and digitalisation deserve a further research. Future research should continue to focus on causality, including qualitative analysis of value chain performance, path analysis, predictive studies and studies of change over time. Finally, this study is among the first to examine the relationship between coaching, motivation, emotional salary and SM and agribusiness employee job satisfaction. As such, it has only provided an initial perspective on the topic and much more research remains to be done to deepen our understanding.

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Does human capital play an important role in farm size growth? The case of Slovenia

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DOI: 10.30682/nm2101d
JEL codes: C21, C23, I25, Q12, Q18

Abstract

The paper investigates the drivers of farm size and farm size growth in Slovenia during the period 2007-2017 using a farm-level Farm Accountancy Data Network dataset within a quantile regression framework. Farm size growth is measured by growth in utilized agricultural area per farm. The findings suggest that growth in farm land size is driven by initial farm land size and policy subsidy support. Contrary to expectations, human capital does not play an important role in either farm land size or farm land size growth according to quantile regressions. These findings from inter-quantile comparative analysis are important for farm-related structural and rural development policy.

Keywords: *Farm growth, Human capital, Subsidies, Slovenian Farm Accountancy Data Network.*

1. Introduction

It is well known from the literature that the number of farms in developed countries has declined, and also that average farm size has increased (Eastwood *et al.*, 2010; Lowder *et al.*, 2016). The relationship between farm size and farm size growth indicates structural changes in farms with implications for farm policy and managerial farm practices and competitiveness. The claim that the relationship between farm/firm size growth and farm/firm size is independent is known in the literature as Gibrat's (1931) Law (Distante *et al.*, 2018). The motivation behind this paper is a desire to move a step beyond testing the validity of Gibrat's Law and investigate the drivers of Slovenian farm size growth to better understand the mechanisms of farm structural change, and the key drivers that influence the observed trends in farm size growth.

In empirical studies, several factors have been identified as influencing farm structural change, including relative prices, technological change, size economies, farm debt, sunk costs, policy variables, demographic variables, and indicators related to off-farm employment and regionally specific patterns and spatial dependencies (Goddard *et al.*, 2002; 2006; Huettel and Jongeneel, 2011). Akimowicz *et al.* (2013) developed and tested a model of drivers of farm size growth in Southwestern France. Barbosa (2020) investigated Portuguese farming firms' growth, focusing on human capital and managerial capa-

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bilities, while Adinolfi *et al.* (2020) investigated gender differences in farm entrepreneurship and farming performance in Italy. Although there is literature about structural change in agriculture, our understanding of different patterns of structural change is limited.

The farm size required (in terms of economies of size in the short term, and scale and scope economies in the long term) to reach (steady) equilibrium can be determined by various factors (Jones and Kalmi, 2012; Akimowicz *et al.*, 2013; Adamopoulos and Restuccia, 2014; Gollin, 2019). Our aim is to specify and establish a robust relationship between farm size growth and its driving forces in terms of farm-specific utilized agricultural area (UAA) and the share of rented land, farmer/manager personal- or human-capital-related factors (age, education/training, and gender), policy factors (subsidies), and territorial or rural variables. It is known from the literature that farms are heterogeneous and that the dynamics of structural change differ between countries and farm-size categories over time (Upton and Haworth, 1987; Johnson and Ruttan, 1994; Weersink, 2018; Colombo *et al.*, 2018).

In comparison to previous studies, this paper adds to the exiting literature by specifying the drivers of farm size growth while controlling for potential farm-specific effects that could influence the results. As novelty is the use of quantile regression techniques and the implications of this methodological approach with additional information that can provide in comparison to more conventional regression methods. The shape of farm size distribution across quantiles can provide a better understanding of the structure of these effects, which can differ across quantiles. Finally, in addition to the contribution the research makes to the literature, the importance of this paper for farm structural policy is related to its use of inter-quantile comparative analyses. It is thus also of relevance to rural development policies and farm managerial and entrepreneurial practices that involve responding to a changing institutional and policy-enabling environment.

The rest of the paper is organized as follows. First, we briefly describe pre-existing literature about firm/farm size growth. Then, we present the methodology, data, and the empirical results of quantile regressions. This is followed by a discussion and description of the implications of the results. The final section derives the main conclusions.

2. Pre-existing literature

In the literature there is no a single measure of farm size (Lund, 1983; Lund and Price, 1998; Alvarez and Arias, 2004) and different measures have been used to capture this factor, such as the physical magnitude of inputs (e.g. total UAA per farm, or total head of livestock per farm), and the economic size of outputs. Akimowicz *et al.* (2013) argue that the choice of UAA per farm may be a more relevant measure of farm size than one related to economic farm size due to the variability of farm production choices and commodity prices over time. Similarly, in our study, UAA per farm is used as a measure of farm size and farm size growth. Farm size growth measured as an increase in UAA per farm may be limited by the quantity of UAA that is available and the number of farms. While a part of UAA can be dedicated to non-agricultural uses and vice versa, a decrease in the number of farms can determine the increase in the remaining average farm size, which can thus be differently distributed over time.

One strand of literature focuses on the drivers of farm size growth using Gibrat's Law of proportionate growth, which specifies that farm size growth is unrelated to initial farm size. The idea that no equilibrium farm size exists may suggest that farm size growth is a random phenomenon. Empirical research has yielded rather contradictory results about the relationship between farm size and the growth of farm size by country and over time. Some studies (Weiss, 1998; Rizov and Mathijs, 2003; Bakucs and Fertő, 2009) have rejected the validity of Gibrat's Law for farm size growth, finding that small farms tend to grow faster than large ones. Other studies (Kostov *et al.*, 2005) found no evidence to reject the validity of Gibrat's Law. Bakucs *et al.* (2013) investigated the relationship between farm size and farm size growth in field crop and dairy farms in France, Hungary, and Slovenia using quantile regression. The results for Hungary are consistent with previous studies that suggested that Gibrat's Law should be rejected because smaller farms grow faster than their larger counterparts. Similarly, the validity of Gibrat's Law can be rejected for French and Slovenian dairy farms, but not for Slovenian crops farms, because the rate of growth of crop farms in terms of land is independent of their size. Bojnec and Fertő (2020a) investigated the validity of Gibrat's Law for the growth of a sample of Slovenian farms in the period 2007-2015 using a cross-sectional dependence test and four different groups of panel unit root tests. The results confirmed the validity of Gibrat's Law independent of measures of farm size (inputs in the form of land and labour per farm, and outputs as economic size per farm) and type of panel unit root test. All farm sizes witnessed an increase in average farm size. Bojnec and Fertő (2020b) compared the growth of Hungarian and Slovenian samples of farms using quantile regression for the period 2007-2015. Results suggested rejecting the validity of Gibrat's Law for Hungarian farms, and, to a lesser extent, for Slovenian farms when the growth of farms was measured by growth of output per farm (where smaller farms grew faster than the largest farms), but not in relation to an increase in farm inputs (i.e. land and labour per farm). Smaller, mostly individual Hungarian farms grew faster than larger, mostly corporate farms.

Akimowicz *et al.* (2013) investigated drivers of farm size growth in Southwestern France. The former examined the factors that can explain farm size growth in developed countries, among them farm structural change (which can be expressed by the diversification of farm activities, farm mechanization, and specialization), the search for an equilibrium farm size or economies of scale or economies of scope, farmer- and human-capital-related factors, other classical factors, and territorial spatial factors that depend on farm location. Farm mechanization and specialization may be important drivers of farm structural change and farm size growth, generating economies of scale (Chavas, 2001). Some previous studies have highlighted that farm size can be determined by human capital and managerial capabilities (Barbosa, 2020) such as farmer age, the experience of the former in the agricultural sector, their level of schooling, and the management techniques that are applied (Sumner and Leiby, 1982).

Akimowicz *et al.* (2013) found that farm size growth was significantly driven by farm structural characteristics, the farmer's age, the existence of a successor, and spatial rural-urban influences, but not human capital variables. Similarly to the area of interest of Akimowicz *et al.* (2013), our paper focuses on drivers of farm size growth and the intensity of farm size growth by different quantiles. We investigate the drivers of farm land size and farm land size growth in Slovenian agriculture with a focus on initial farm size in terms of UAA per farm and the share of rented land, farmer/manager personal- or human-capital-related factors (age, education/training, and gender), farm subsidies, and farm location in rural areas. Our main hypothesis is that farmer/manager personal- or human-capital-related variables are positively related to land farm size distribution and land farm size growth (Sumner and Leiby, 1987; Barbosa, 2020). However, Akimowicz *et al.* (2013) and Barbosa (2020) have reported mixed findings in relation to different farmer/manager personal and human capital variables.

3. Methodology

Different econometric approaches have been developed in the literature to test the validity of Gibrat's Law (the relationship between farm size and farm size growth). Studies of drivers of farm size growth, in addition to initial farm size, include various control variables related to farm-specific variables on the input and output side, as well as policy and territorial factors (Akimowicz *et al.*, 2013).

The econometric specification of the regression used specifically for testing the validity of Gibrat's Law with the definition of model variables is the following equation (1), which represents the stochastic process underlying Gibrat's (1931) Law:

$$\frac{S_{i,t}}{S_{i,t-1}} = \alpha S_{i,t-1}^{\beta_1 - 1} \varepsilon_{i,t} \tag{1}$$

where $S_{i,t}$ and $S_{i,t-1}$ are the size of the i^{th} farm in the period t and in the previous period t-1, respectively. $\varepsilon_{i,t}$ is the disturbance in period t, independent of $S_{i,t-1}$. α is the common growth rate of all farms, whilst β_1 measures the effect of initial size upon the given farm's growth rate. If $\beta_1 = 1$, then farm size growth rate and initial farm size are independently distributed, indicating that Gibrat's Law holds. If the coefficient is less than one, it follows that small farms tend to grow faster than large farms, while the opposite is the case if β_1 is greater than unity.

Rewriting equation (1) in the form represented by equation (2) allows for the testing of the significance of the coefficient β_1:

$$\log S_{i,t} = \beta_0 + \beta_1 \log S_{i,t-1} + \mu_{i.t} \qquad (2)$$

where $\beta_0 = \log\alpha$ and $\mu_{i,t} = \log\varepsilon_{i,t}$, where log is the natural logarithm. Following Ward and McKillop (2005), if $\beta_1 = 1$ (i.e. Gibrat's Law holds), then positive (negative) values of β_0 indicate growth (decrease) in average farm size. If, however, $\beta_1 < 1$, then smaller farms tend to grow faster than larger ones.

The growth model is modified by redefining the dependent variable as the first difference of the logarithm of farm land in equation (2):

$$logS_{it} - logS_{it-n} = \beta_0 + \beta_1 S_{it-n} + X_{it-1}\gamma + \mu_{it} \qquad (3)$$

where X_{it-1} represents a group of additional covariates.

In the OLS regression estimation, error terms are assumed to follow the same distribution irrespective of the value of the explanatory variables. Since we can only analyse surviving farms, estimations are conditional on survival (*conditional objects*, see Lotti *et al.*, 2003).

Empirical studies on land-use and land-cover change with impact on landscape have applied different methodological approaches in literature to study and predict farm size and farm size growth, its drivers and causes from smart farming towards agriculture 5.0, including econometric, agent-based models (Parker *et al.*, 2002; Beckers *et al.*, 2018), stellate model, and machine learning technics (Pantazi *et al.*, 2016; Wolfert *et al.*, 2017; Rudd *et al.*, 2017; Saiz-Rubio and Rovira-Más, 2020; Mekonnen *et al.*, 2020). Among methodological approaches particularly related to spatially land-use and land-cover change models we have selected the econometric approach with applied the quantile regression models to study drivers of farm size distribution across quantiles.

Therefore, in this paper we use the quantile regression estimation technique. Following Lotti *et al.* (2003), the θ^{th} sample quantile, where $0 < \theta < 1$, can be defined as:

$$\min_{b \in R}\left[\sum_{i \in \{i: y_i \geq b\}} \theta |y_i - b| + \sum_{i \in \{i: y_i < b\}} (1-\theta)|y_i - b|\right] \qquad (4)$$

where y_i and b are estimated for any quantile within the range of zero and one.

For a linear model such as $y_i = \beta' x_i + \varepsilon_i$, the θ^{th} regression quantile is the solution of the minimization problem, similar to equation (4):

$$\min_{b \in R^k}\left[\sum_{i \in \{i: y_i \geq x_i b\}} \theta |y_i - x_i b| + \sum_{i \in \{i: y_i < x_i b\}} (1-\theta)|y_i - x_i b|\right] \qquad (5)$$

Solving equation (5) for *b* provides a robust estimate of β.

To keep the same farms in the balanced panel dataset during the analysed period, the sample size reduces considerably. Nikitina *et al.* (2019) suggests to apply bootstrapped quantile regression approach for small sample size. We have addressed small sample size issue applying bootstrapped quantile regression models with bootstrapped standard errors using 1000 replications.

4. Data

We employ farm-level data from the Slovenian Farm Accountancy Data Network (FADN) sample of farms to analyse drivers of farm land size and farm land size growth during the period 2007-2017. We use farmer/manager personal- or human-capital-related variables: age, education/training (defined as 1: primary school, 2: high school, 3: university), and a gender dummy which is equal to one if farmer is female, and zero for male. Rural is a dummy variable which takes a value of one if the farm is located in a rural area in terms of the European Commission classification, and is zero otherwise. As a policy variable, we use total subsidies in euros (SE605). The Statistical Office of Slovenia (SORS) price indices are used as deflators of nominal values over time with a 2010 base year. We use balanced panel data.

5. Results

We first present descriptive statistics and then econometric models.

5.1. *Descriptive statistics*

Table 1 illustrates the averages of farm size and explanatory variables in the reference year 2007 and the final analysed year 2017. UAA farm size is used as the farm size variable. The average size of farmland in UAA was 16.4 ha per farm in 2007, while the largest farm in the sample was 110.6 ha. Average farm size increased by 0.9 hectares between 2007 and 2017. Farms in Slovenia are still largely cultivating their own land, although the share of rented land has stabilised. In 2007 and 2017, on average 30% and 29%, respectively, of land was rented (ranging from farmers cultivating only their own land – i.e. no rented land –, to farms operating on completely rented land, the latter situation more often being the case with the few privatized commercial farms which typically rent land from the state fund for agricultural land and forests). Subsidies are an important source of farm income. For the analysed sample of farms, they increased at constant prices of 2010 from 9,667 euro per farm in 2007 to 11,187 euro per farm in 2017. Most farm managers and farm owners have some kind of agricultural education, which has increased during the analysed period. Their average age in the reference year 2007 was 42.8 years and in the final year 2017 was 52.2 years, while during the period of analysis the average age was 48.3 years, and 81% farm managers and farm owners were male.

To present density estimation on grouped data graphically in the case of mean values of farm size expressed in UAA in ha per farm, we use a comparison of kernel density distribution function with parametric estimation of the Lorenz curve which is also applied to grouped data.

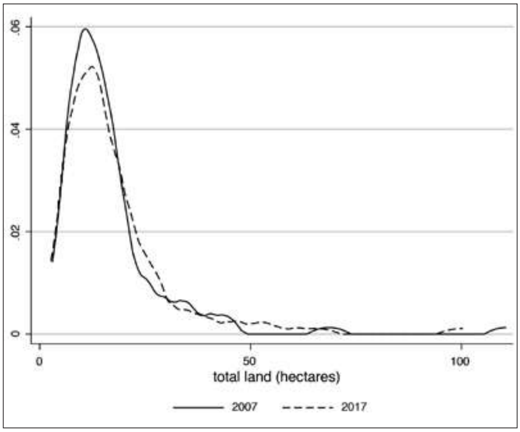
While there were no radical changes in farm size land distribution between 2007 and 2017, the kernel distribution function for land (UAA in ha per farm) in Figure 1 confirms a slight shift in average farm size land concentration towards rights suggesting a slightly larger average farm land size.

Table 1 - Descriptive statistics of variables (reference year 2007 and final year 2017).

Variables	*Number of observations*	*Mean*	*Std. Dev.*	*Min*	*Max*
Land (in UAA in ha) 2007	113	16.4	13.4	3.0	110.6
Land (in UAA in ha) 2017	113	17.3	13.7	2.7	100.2
Age (in years) 2007	113	42.8	13.3	14.0	73.0
Age (in years) 2017	113	52.2	13.5	23.0	83.0
Training dummy 2007	113	1.44	0.63	1.00	3.00
Training dummy 2017	113	1.63	0.68	1.00	3.00
Gender dummy 2007	113	0.19	0.39	0.00	1.00
Gender dummy 2017	113	0.19	0.39	0.00	1.00
Rented land (in %) 2007	113	30	28.1	0.00	100
Rented land (in %) 2017	113	29	27.4	0.00	100
Total subsidy (in euro) 2007	113	9667.1	8921.1	0.0	66601.0
Total subsidy (in euro) 2017	113	11186.9	10934.6	1175.0	66013.6

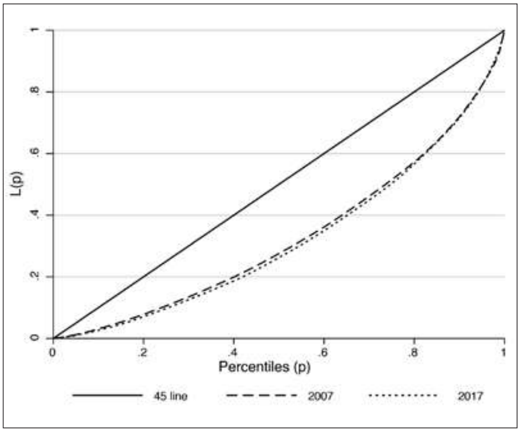
Source: Authors' estimations based on FADN data.

Figure 1 - Kernel distribution function for land (UAA in ha per farm).



Source: Authors' estimations based on FADN data.

Figure 2 - Lorenz curves for land distribution (UAA in ha per farm).



Source: Authors' estimations based on FADN data.

A slight increase in average land farm size is seen from the Lorenz curves for the distribution of land in UAA in ha per farm (Figure 2). Finally, Lorenz curves of farm size land distribution close to the 45° line, which means a linear distribution, suggest a more equal than unequal land farm size distribution in the Slovenian farming structure.

5.2. *Econometric models*

We test two econometric models that were designed to explain two aspects of farm size growth. First, the logarithm of farm size observed in 2007 expressed in terms of UAA per farm, specified as log (land in UAA) per farm in 2007. Second, the logarithm of the intensity of growth between 2007 and 2017, the period for when growth is, as expressed in equation (3). The aim of using the two models was to compare the effect of the explanatory variables on indicators of farm size and their evolution. The first regression reveals the impacts of various factors on initial farm size. The second regression focuses on the effects of the same explanatory variables on the intensity of farm size growth. Notice that the explanatory variables we employed concerned the year 2007, and these are the initial characteristics likely to explain the variation in farm size, and, more particularly, the growth in farm size in terms of both variables observed in 2017.

Table 2 presents quantile regressions of log (land in UAA) per farm in 2007. The results of these quantile regressions are mixed and suggest that agricultural education/training has a negative impact for q10, but is insignificant for the remaining quantiles. The cultivation and operation of the smallest farms requires less knowledge and experience. Farm growth is positively linked to the proportion of rented land and log (subsidy) received by all quantiles. As subsidy payments are input-based, there was a positive link between subsidies and the growth of farm size in UAA from 2007 onwards. Farm size growth is negatively linked to the variable female for q90, while for other quantiles the role of gender in farm size growth is insignificant. Also insignificant is the role of the age and rural dummies on farm size growth by all quantiles. We also estimated our models with squared age variable, but the coefficients were insignificant for both level and squared terms in all quantiles. Therefore, except for training and gender, no other considerable inter-quantile differences can explain the structural changes in the farming sector and/or potential changes in (nor specificity of) technology related to UAA per farm size growth since 2007. A significant positive influence for farm size growth of log (land in UAA) per farm in 2007 is mainly caused by the share of rented land and subsidies, with some differences in magnitude across quantiles.

Table 2 - Quantile regression for farm land size: log (land in UAA) per farm in 2007.

	q10	*q25*	*q50*	*q75*	*q90*
Age	-0.001	0.000	0.000	0.001	0.001
Training	-0.095***	-0.030	0.039	0.023	0.030
Gender	-0.042	-0.035	-0.030	-0.079	-0.329***
Rented land	0.463***	0.448***	0.334**	0.659***	0.456*
log (subsidy)	0.777***	0.738***	0.678***	0.589***	0.518***
Rural	0.018	0.036	-0.029	0.009	-0.205
Constant	-4.605***	-4.351***	-3.637***	-2.773***	-1.633
Number of observations	109	109	109	109	109
Pseudo R^2	0.6066	0.5408	0.5069	0.4917	0.5019

*Note: *** p<0.01, ** p<0.05, * p<0.1.*

Table 3 presents the results of quantile regression for land size changes specified as log (land in UAA) per farm between 2007 and 2017. Farm size growth between 2007 and 2017 is negatively linked with initial land farm size, which is, except for q10, statistically significant by quantile. In contrast, farm land size growth is positively associated with log (subsidy) payments, which are, except for q10, statistically significant by quantile. Female farm owners and managers negatively influence farm land size growth for q50 and q75, and are otherwise insignificant for other quantiles. The non-linear impact (by quantile) on farm land size growth is related to the proportion of rented land, which is significantly positive for q50 and q75. In addition, except for q10, log (subsidy) by quantile is positive and significant. The impact of age is, except for q25, insignificant (negatively influencing farm land size growth in q25). The impact of education/training and rural is insignificant.

Table 3 - Quantile regression for farm land size changes: log (land in UAA) per farm between 2017 and 2007.

	q10	*q25*	*q50*	*q75*	*q90*
log (land)	-0.370	-0.269***	-0.294***	-0.297***	-0.232*
Age	-0.005	-0.003*	-0.002	-0.003	0.002
Training	-0.025	0.016	0.014	0.004	-0.071
Gender	0.022	-0.011	-0.080*	-0.096*	-0.140
Rented land	0.079	0.060	0.209**	0.216*	0.147
log (subsidy)	0.236	0.223***	0.210***	0.241***	0.265***
Rural	0.009	0.032	-0.005	-0.049	0.046
Constant	-1.131	-1.326***	-1.063***	-1.151**	-1.463**
N	109	109	109	109	109
Pseudo R^2	0.2088	0.1042	0.0627	0.1005	0.1117

*Note: *** p<0.01, ** p<0.05, * p<0.1.*

6. Discussion and implications

Farm size distribution, farm structural changes, and drivers of farm size growth are some of the most often studied research issues in agricultural economics (Sumner, 2014). They are also common subjects of agricultural and rural development policy objectives related to diversified spatial farming structures in developed and developing countries and are considered important variables in relation to competitiveness, and agricultural and farm sustainable development (Key and Roberts, 2007; Piet *et al.*, 2012; Bartolini and Viaggi, 2013). According to the 2010 General Agricultural Census (Eurostat, 2020a) and the 2016 Farm Structure Survey (Eurostat, 2020b), farm fragmentation of the smallest farms, farm concentration of the largest farms, and farm size growth vary considerably across EU-28 member states. The heterogeneity in farm size distribution has also been confirmed by the typology and distribution of small farms in Europe (European Commission, 2013; D'Amico *et al.*, 2013; Guiomar *et al.*, 2018).

Our analysis focuses specifically on a sample of Slovenian FADN farms. Slovenia can be classified as one of a number of EU-28 member states that have on average smaller but growing average farm size (Bojnec and Fertő, 2020a; 2020b). Similarly to some other countries, farm exit occurs particularly among farms of medium size in Slovenia (Bojnec and Latruffe, 2013).

The present study has confirmed five main findings that have farm managerial and policy implications. First, there is a negative relationship between initial farm land size and farm land size growth. This suggests that large farms are growing less than small ones, confirming earlier results for Slovenian agriculture (Bakucs *et al.*, 2013). The policy insight is that different initial farm sizes are an important variable in farm size growth and diversification (Melhim *et al.*, 2009). In the short term, this may be connected to an increase in economies of size, while in the long term it may be associated with a combination of both scope economies for smaller and mixed farms, and scale economies for larger and more specialized farms (in terms of land use). Among the latter farms, this may involve larger specialized crops farms, and more extensive livestock and dairy production on grassland (i.e., widespread pastures and meadows, particularly in less favoured hilly and mountain areas).

Second, in contrast to theoretical expectations, farmer-specific personal characteristics and human-capital-related variables do not play an important role in farm land size and farm land size growth (Sumner and Leiby, 1982). This a striking finding, although the situation regarding farmer/manager education/training for Slovenia is similar, for example, to that identified by Akimowicz *et al.* (2013) for Southwestern France. However, in Slovenia, the age of farmers was found to be insignificant across quantiles, while greater female participation reduces farm land size and farm land size growth in upper quantiles. Therefore, farmer/manager-specific personal characteristics and human-capital-related variables were largely found to be an insignificant driver of farm land size and farm land size growth for the Slovenian sample of FADN farms for most quantiles.

Third, a greater share of rented land is associated with greater farm land size, and, to a lesser extent, contributes to farm land size growth for upper quantiles, except for the largest farm land size, which might indicate limitations in terms of further farm land size growth. These findings suggest that the renting of land and land-leasing arrangements have become an important driver in the restructuring of the Slovenian farming structure towards farm size growth. While traditional family farms mostly operated on their own land (traditional or peasant farming), this has changed towards more entrepreneurial operations that involve the renting of land.

Fourth, subsidies positively influence both farm land size and farm land size growth. Accordingly, generous Common Agricultural Policy (CAP) subsidies are found to be a crucial driver of farm land size for all quantiles, and farm land size growth for the Slovenian sample of FADN farms by quantile, except for the lowest q10. This finding may be important from a farm managerial perspective, as CAP subsidies can be an important driver of farm profitability and a relatively stable source of farm revenue, but are also policy – and thus politically dependent. CAP subsidies in Slovenian agriculture have been found not only to be important, but also one of the most stable sources of farm income (Bojnec and Fertő, 2018; 2019a; 2019b). However, offering generous CAP subsidies has important policy implications. Any changes or reductions in CAP subsidies could have a diminishing effect on farm land size, with the potential abandonment of operations, particularly in depopulated, remote, and less favoured areas, and generally on farm land size growth in Slovenia. However, Unay-Gailhard and Bojnec (2019) find that agri-environmental policy measures supported with subsidies can create green jobs on Slovenian farms, particularly in relation to family labour on large dairy family farms and hired labour in large field crop farms. On the other hand, Baráth *et al.* (2020) did not find a significant effect for three different types of subsidies – investment-, less-favoured-area-, and agri-environmental subsidies – on total factor productivity and its three different components (technical efficiency, scale efficiency, and technological change) in Slovenian agriculture during the period 2006-2013. Therefore, as public budgets and subsidies are limited and politically dependent on CAP changes, there is a need to improve the targeting, management, and monitoring of efficiency in subsidy implementation: a crucial implication for policy, managerial, and farm entrepreneurial practices.

Shifting from a government-supported to a more entrepreneurial farming structure (probably involving a decrease in subsidies) requires improvements of the institutional and organizational structure of farming and in agri-food value chains such as promoting the role of farmer-based organizations for value chain integration (Francesconi and Wouterse, 2015) and networking for small farms as a factor for entrepreneurship (Aubert and Perrier-Cornet, 2009; De Hoyos-Ruperto *et al.*, 2013; Ciliberti *et al.*, 2020). A greater role can play by changes in farm income diversification and farm income sources on entrepreneurially oriented farms and small- and medium-sized enterprises (Gričar *et al.*, 2019). More entrepreneurial farms and farm size growth can be combined through new technological innovation, including open innovation from outside farms and the greater transfer of knowledge into farming and agri-food value chain practices. Different types of innovation approaches may include product innovation involving the implementation of new or significantly improved products or services (OECD, 2009), process innovation with new or improved farm production technologies or delivery methods for increasing added value (such as in short-supply chains in local agri-food markets and in online agri-food shopping), marketing innovation through different marketing channels to obtain higher prices, and organisational innovation that leverages economies of scale for relatively small- and medium-size farms, such as setting-up producer associations and making improvements in service cooperatives (e.g. in their organisation and communication) and contract farming that can improve efficiency and add value (OECD, 2015; Benke and Tomkins, 2017; Mishra *et al.*, 2018).

Finally, farm growth may be related to some other factors, among them farm investment, where an important role may be played by financial constraints, farm efficiency, and financial status or farm indebtedness (Bojnec and Fertő, 2016). As argued by Fagiolo and Luzzi (2006) for the Italian manufacturing industry and Donati (2016) for the manufacturing and service sectors in Italy, firm size and firm size growth can be explained by liquidity constraints. Farm growth can also be heterogeneous in relation to types of farming and natural factor endowments and in terms of locational factors and regional specificities. Baráth *et al.* (2018) investigated and compared the effect of heterogeneity on production technology and technical efficiency for a sample of less- favoured-area and non less-favoured-area Slovenian FADN farms. The striking finding was that farms in less-favoured-areas are not more inefficient, but rather use different, production-environment-specific technologies.

7. Conclusions

This paper deals with the drivers of farm land size and farm land size growth in Slovenia. It adds to the existing literature evidence on the drivers of farm size and farm size growth with important farm managerial and policy implications. The analysis does control for possible farm-specific effect influencing the results. The main findings lead to the conclusion that initial farm size and CAP subsidies are the main drivers of farm land size and farm land size growth in Slovenia. However, the results suggest some diversity across different quantiles.

The main novelty lies in the application of advanced quantile regression econometric methodology to FADN farm level data using more explanatory variables. The paper starts with the hypothesis that farmer/manager personal or human capital variables can play a positive role in land farm size and land farm size growth. However, the results suggest that farmer/manager-specific personal characteristics and human-capital-related variables were largely found to be insignificant according to quantiles for farm land size and farm land size growth in Slovenia. The negative relationship between initial farmland size and farm land size growth suggests that large farms are growing less than small ones. In terms of farm land size and farm land size growth, the impact of generous CAP subsidies exceeded that of all other drivers. Renting of land and land leasing arrangements have become an important driver of restructuring of the Slovenian farming structures.

The findings from this study can be applied in the more general setting of farm size growth when relatively small- to medium-sized farms dominate farming structures. This is the situation in the countries neighbouring Slovenia on the territory of the former Yugoslavia that share a common recent (20th century) history, as well as for some other transition and emerging market economies that are experiencing structural changes in the farming sector. In addition to increasing understanding of the drivers of farm restructuring and farm size growth, the findings are also important for agricultural and rural development policy. Agricultural policy can target different farm size structures, an approach which may be important for farm competitiveness on an international basis, and changes in rural factor markets. In addition to land market and land leasing arrangements, the former can cause changes in local labour market conditions and increase local employment. The finding that an important driver of change in the farming sector may be the age of farmers/farm managers could be of crucial importance for farm labour renewal and long-term farm survival, but may be also a factor of importance in farm investment activities which can create rural jobs and increase the competitiveness of farming and the rural economy. These structural changes in farms can be supported with CAP measures for young farmers and investment subsidies, or non-CAP funds such as regional and cohesion funds.

Among the study limitations, only input-oriented UAA per farm is used as a measure of the relationship of farm land size to farm land size growth. In terms of the implications of the study comparison, this assumption should be contrasted with the use of other different input- (e.g. labour, livestock, and capital) or output-oriented farm size/farm size growth measures. The findings and implications might have been different if different farm size measures had been used. Finally, farm size growth can be also driven by other factors that were not specified in our study, such as type of farming and regional specificities, the use of different farming technologies, off-farm employment, different market structures, and production and market risks. These are issues for future research.

Acknowledgements

This study was supported with funding received from the Hungarian and Slovenian Research Agencies as a joint research project within Project N5-0094 - *Impacts of agricultural policy on the regional adjustment in agriculture: A Hungarian-Slovenian comparison*.

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Farmers' perception regarding climate change in Southern Turkey: The case of the Mersin province

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DOI: 10.30682/nm2101e
JEL codes: C23, Q12, Q54

Abstract

Climate change is responsible for the negative effects on human life causing a decrease in agricultural products availability, biodiversity, soil fertility, and forest areas. Moreover, climate change increases plant diseases and pests, the cost of agricultural production and risk in food security. This study aims to determine whether climate change is a phenomenon via the analysis of the perceptions of the farmers regarding this issue in the Mersin province conducted through 251 questionnaires. Farmers primarily perceive climate change through production costs and the reduction in yield. Moreover, they are highly aware of its relation to natural events such as floods, drought, and storms. Nevertheless, inappropriate agricultural practices too have led to the negative consequences caused by climate change. In this respect, this study has revealed that farmers with strong cooperative partnerships and experience perceived climate change significantly.

Keywords: *Farmers' perception, Climate change, Mann-Kendall, Sen's Slope*

1. Introduction

Climate change remains one of the most important environmental threats for both humans and all life forms including plants, animals and other living things worldwide (Nakicenovic *et al*., 2000). The global average of surface temperature has increased by 0.74 °C in the last century. This is the highest temperature rise recorded in the last 12 years, according to data dating back to 1850. More severe and longer droughts have been observed since the 1970s in the midlatitudes (IPCC, 2012). In particular, Turkey, located in the eastern parts of the Mediterranean Basin, is one of the most vulnerable regions to climate change, as identified by the fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2012). In this context, the average air temperature rose by 0.64 °C and precipitation decreased by 29 mm from 1941 to 2007 in Turkey, where this increase was generally encountered in the annual maximum and minimum temperature series and was statistically significant in the south of the country. Furthermore, significant decreases in precipitation and number of rainy days were also observed especially in the winter mostly along

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the Mediterranean coast (IPCC, 2013). Nevertheless, this reveals that the impacts of climate change have become inevitable and should be studied on regional scale.

Consequently, climate change will heavily affect agricultural production systems, and farmers' living conditions and lifestyle (Dellal *et al*., 2011; Tsujii and Gültekin, 2019). Forecasting the possible effects of climate change on agricultural production and the adoption of appropriate farming techniques by farmers in order to mitigate to negative effects of climate change is vital for the future generation. A great deal of empirical study has measured the effects of climate change on agriculture and the measures to be taken in order to reduce and/or minimize these negative effects in Turkey (Kanber *et al*., 2008; Dellal *et al*., 2011; Akyuz and Atis, 2016; Dumrul and Kilicaslan, 2017; Karakas and Dogan, 2018; Bozoglu *et al*., 2019; Tsujii and Gültekin, 2019). The common conclusions raised in the aforementioned studies are that, depending on climate change, there may be a decrease in the productivity of agricultural products and an increase in the prices. And also, the authors stated that these negative consequences could be mitigated by establishing appropriate policies, strategies, plans, and programs. Some policy recommendations have been developed in these studies to mitigate the negative effects of climate change.

In order to encourage farmers to adopt agricultural practices to mitigate the negative effects of climate change, it is necessary to understand how they perceive climate change and develop appropriate intervention tools. So, As well as to empirical results, policy makers should pay special attention to the perceptions of farmers who implement the measures to be taken to mitigate the effects of climate change. However, the analysis of the farmers' perception of climate change was seen as a deficiency in Turkey. We found only three studies which estimated WTP for the adaptation of agricultural practices to mitigate the effects of climate change in Turkey (Aydogdu and Yenigün, 2016; Öz, 2019; Polat and Dellal, 2016). However, this topic has received great attention in foreign literature in recent years (Akhtar *et al*., 2018; Hameso, 2017; Lane *et al*., 2017; Ndamani and Watanabe, 2017). So, the main objectives of this study are to analyze farmers' climate change perception and its determinants in Mersin Province where located in the southern part of Turkey. Furthermore, the Mann-Kendall trend analysis and Sen's slope estimate has been employed to monitor the change in rainfall, average temperature, and relative humidity to provide evidence about the climate change phenomenon in the study area, based on data belonging to the period 1959-2019. Main reason selected of Mersin as the research area is that Dudu and Çakmak (2018) stated that the effects of climate change on the economy will be drastic changes both in agricultural production and commodity prices in Turkey. And also, they reported that climate shocks will severely affect agricultural products and food commodities, but coastal regions will be affected relatively less until the 2060s. So, this may be seen as an advantage for taking precautionary measures to mitigate the adverse effects of climate change in Mersin. In this study, the perceptions of farmers regarding climate change were analyzed and it was confirmed that climate change is a phenomenon in the region under study with meteorological data. This is the difference between this study and other studies conducted in Turkey.

In this study, it was determined that climate change is a real phenomenon in the Mersin based on meteorological data. The understanding of farmers' climate change perception in Mersin Province of Turkey is important. The findings of this study might be useful to develop and implement interventions that are in keeping with farmers' perception to mitigate the negative effect of climate change on agriculture. For example, farmers believe that climate change will cause an increase in agricultural costs. For this reason, economic interventions can be used to face climate change. Also, understanding farmers' perceptions and thoughts on climate change is a key factor to increase the adoption of the best agricultural practices for dealing with climate change. Daly-Hassen *et al*., (2019) statted that the adoption of the best agricultural practices to mitigate the negative effects of climate change provides benefits from a regional, global, and societal point of view.

The remainder of the study is organized as follows: Section 2 deals with materials and methods; Section 3 presents a discussion on the results, and Section 4 presents the conclusions.

2. Materials and methods

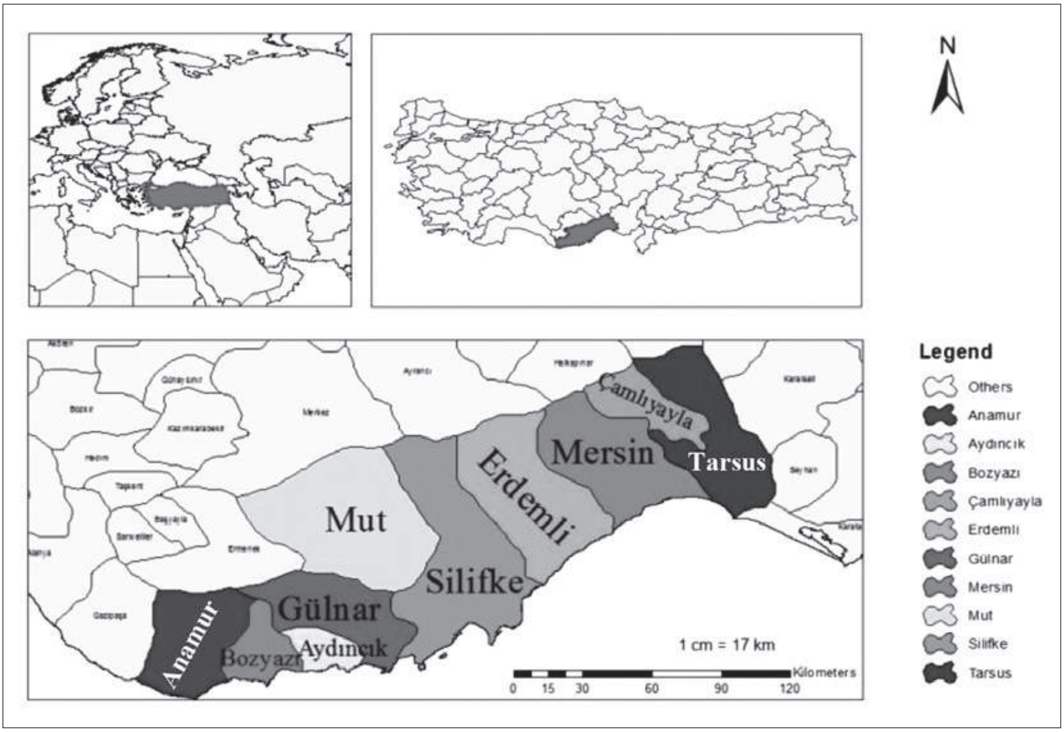
Research Area and field data

The data used in this study came from the surveys conducted in the Mersin province. A cross-sectional survey method was used in this study during the period of May-August 2019. The research data were collected from 251 randomly selected farmers in Mersin through experienced enumerators (Figure 1). The data collection tool was a structured questionnaire which consisted of two parts. The first section consisted of information on socio-economic characteristics of farmers. The second section was a list of 14 items designed to assess the farmers' climate change perceptions. These were prepared taking into account the previous studies on climate change (Akhtar *et al*., 2018); Hameso, 2017; Lane *et al*., 2017; Ndamani and Watanabe, 2017). The 14 items are presented in Table 2. The reliability of the climate change perception scale was estimated by calculating Cronbach's alpha coefficient (Cronbach, 1951) which amounted to 0.933.

Data analysis

In this study, descriptive statistics (mean and standard deviation), multiple linear regression analysis and factor analysis (Principal Component Analysis - PCA) were used. Descriptive statistics such as the mean and standard deviation were used in order to delineate farmers' socio-economics characteristics. And then, Factor analysis (PCA) was applied to the climate change perception scale. Kaiser-Maier-Olkin (KMO) and Bartlett's sphericity test were used to verify the suitability of scale for PCA. The results of KMO (the KMO value was 0.920) and the significance of Bartlett's sphericity test (p value was 0.000) confirmed that scale and data suitable for PCA. The number of factors selected was based on the Kaiser's criterion, where only factors with eigenvalues greater than 1.00

Figure 1 - Mersin province.



were selected. Using factors scores from PCA as dependent variable, a multiple linear regression analysis was used to determine the influence of some socioeconomics variables on the farmers' climate change perceptions (Gujarati, 2009).

Climate data analysis techniques

Farming activities depend on climate conditions and are at risk via a changing climate (Porter *et al.*, 2014); thus it would be expected that farmers have a long-term point of view on climate because of its direct effect on their welfare (Niles and Mueller, 2016). However, we do not know of any studies that have analyzed the farmers' perception of climate change, tracking observed climate changes at the same time. To that end, we applied a trend analysis in this study area to detect the change of climate parameters on a seasonal basis. Temperature, rainfalls and relative humidity are the most significant variables in the field of climate sciences usually used to detect the magnitude of climate change (IPCC, 2007; Asfaw *et al.*, 2018). Despite the available information on climate trends stored in the archives of the State Meteorological Office of Turkey, there is no definite guidance or research conducted using the data of the Mersin province. Furthermore, some previous studies that did not include the data of the last decades focused on the trends of the surface climatic variables, such as Türkeş *et al*. (1995), used Mann-Kendall nonparametric test to identify trends in the long-term mean temperature of both individual stations and geographical regions in Turkey during the period 1930-1992. Kadıoğlu, (1997), examined trends in the mean annual temperature records during the period 1939-1989 in the eighteen stations across Turkey. Partal and Kahya (2006) detected the trend of rainfall records at 96 stations by using the monthly total precipitation variables from 1929 to 1993. Thus, in this study the data used consist of the monthly time series of near-surface meteorological variables observed at 4 meteorological stations (Mersin, Erdemli, Silifke, Anamur) from the State Meteorological Office of Turkey, including: the mean air temperature (°C), rainfall (mm) and relative humidity (%). The major considerations for selecting these stations were the following: spatial distribution of the stations across the region; availability of the longest possible records within the period of 1959-2019, and completeness of the records without missing data points. In accordance with this purpose, we use the most common non-parametric test, which is the Mann-Kendall test, to analyze the time series trends. Moreover, Mann-Kendall test is nonparametric; therefore, data outliers do not affect the results (Ahmad *et al*., 2015). Therefore, this test determines whether the data trend is upward or downward over time through what is essentially a non-parametric form of monotonic trend regression analysis (Donald *et al*. 2011).

Mann-Kendall Test

The Mann-Kendall (MK) non-parametric test has been widely used to assess the significance of trends in meteorological time series (Liang *et al.*, 2010; Topaloğlu and Ozfidaner 2012; Liu *et al.*, 2014). This approach needs a few assumptions on the data to be made, especially concerning their distribution. The Mann-Kendall test is based on the null hypothesis that a sample of data is independent and identically distributed, which means that there is no trend or serial correlation among the data points. The alternative hypothesis is that a trend exists in the data (Novotny and Stefan, 2007). The trend test is applied to the data series x_i ranked from i = 1,…, n-1, and x_j is ranked from j = i + 1,…, n. Each data point x_i is used as a reference point and is compared with all other data points x_j so that

$$\operatorname{sgn}(x_j - x_i) \begin{cases} 1 & \text{for } x_j > x_i \\ 0 & \text{for } x_j = x_i \\ -1 & \text{for } x_j < x_i \end{cases} \tag{1}$$

The MK test statistic S is calculated as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i) \tag{2}$$

where n is the length of the data set. The statistic S, when $n \geq 8$, is approximately normally distributed with the mean and the variance given by

$$E[S] = 0 \tag{3}$$

$$\operatorname{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{p} t_i(t_i-1)(2t_i+5)}{18} \tag{4}$$

in which p is the number of tied groups in the data set, and t_i is the number of data points in the *i*th tied group. The summation term in Eq. (4) is only used if data values are tied in the series. The standardized MK statistic Z is computed by

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \ for\ S > 0 \\ 0\ for\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} \ for\ S < 0 \end{cases} \quad (5)$$

and follows the standard normal distribution with the mean of zero and variance of one under the null hypothesis of no trend in the series. The null hypothesis is rejected if $|Z| \geq z_{1-\alpha/2}$ is at the α level of significance, where $z_{1-\alpha/2}$ is the (1-α/2) quantile in the standard normal distribution. A positive Z value indicates an upward trend, whereas a negative value indicates a downward trend. A significance level of 5% will be used in the analysis, which means that there is a 5% uncertainty and, in this respect, it would be correct to reject the null hypothesis that a trend does not exist in the data set.

Sen's Slope Estimate

Various tests exist and can be employed for the detection and/or quantification of the magnitude of the trend. According to the data time series, if a linear trend is detected, the exact slope could be estimated using an uncomplicated nonparametric method given by Sen (1968). Sen's slope estimator inclines in many cases more toward the trend determination of the robust methods and confirms the trend sign and magnitude estimates by applying the robust parametric methods (Muhlbauer *et al*., 2009). Moreover, Sen's slope estimator is generally applied on climate parameters, for instance, see Marofi *et al*. (2012) and Huang *et al*. (2013). The Sen's slope estimator, by calculating the slope of the line using all data value pairs is deter-mined as follows

$$Q_i = \frac{x_j - x_i}{j-k} \quad i = 1,2,\ldots,N \quad \text{where } j > k \quad (6)$$

If there are n values x_j in the time series we get as many as N=n (n-1)/2 slope estimates Q_i. The Sen's slope estimator is the median of these N values of Q_i. The N values of Q_i are ranked from the smallest to the largest and the Sen's estimator is

$$Q = \begin{cases} Q_{\frac{N+1}{2}} \text{if N is odd} \\ \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\frac{N+2}{2}}\right) \text{ if N is even} \end{cases} \quad (7)$$

3. Results and Discussion

3.1. *Trends and the Magnitude of Seasonal Temperature, Rainfall and Relative Humidity Series*

The seasonal mean temperature trend assessment results obtained by the Mann-Kendall test and the magnitude of trend changes of the four meteorological stations in the area under study that were calculated by the nonparametric method of Sen's, are shown in Table 1. Over the period of 1959 to 2019, the Mann-Kendall test confirmed the occurrence of stronger warming trends for the all stations. The significant (14 times) and insignificant upward (2 times) trends were obtained for each seasonal data of the stations. The average warming in the Mersin province in the Mediterranean part of Turkey, was the highest by 2.2 °C 61 $years^{-1}$, in the range 1.5 with 3.2 °C 61 $years^{-1}$ in the summer season and the lowest in winter (1.1 °C/51 years), whereas the rise of the mean temperatures in the autumn and spring tended to be lower than in the summer. The analysis conducted by Türkeş *et al*. (2002), on the dataset of the Turkish mean temperature series of 70 stations with 9 stations located in the Mediterranean region, revealed increasing trends from 1942 to 1999 coinciding with our results. Moreover, Türkeş *et al*. (2002) determined a warming trend of approximately 0.25 °C $decade^{-1}$ in the summer for the Mediterranean region, whereas ours is 0.36 °C $decade^{-1}$. The reason for this could be the different ending period of the data used for which many studies have proven that a change in temperatures has occurred near the 2000s. Moreno *et al.* (2016) introduced that most of the observed warming was due to changes after the year 2000s. The radiative forcing of the climate system has continued to rise during the 2000s, as it was related to the increase in greenhouse gases (IPCC, 2014). Thus, changes in radiative forcing evokes increased warming at the surface (Trenberth, 2011), and this could be the reason for the enhanced warming. In addition to this, the overall annual mean temperature analysis in the area under study revealed a dramatic increase of 1.67 °C over the past 61 years. On the other hand, the differences in the trend rates between the stations could mainly be explained by the urbanization level. Stronger warming trends of annual minimum temperatures are mostly observed in the stations that are rapidly urbanizing or which are already urbanized cities, as in the summer (Türkeş *et al*., 2002). According to our results, the Mersin station has the strongest increase in temperature which is related to higher urbanization compared to the others. In this sense, exposure to increased temperatures causes faster crop development which reduces production and also has negative impacts during the reproductive stage of crop development (Hatfield *et al*., 2011). Higher temperatures also increase the evapotranspiration demand for crops and thus cause greater water stress. Thus, surveying is needed in regions like Mersin to determin the perceptions of the farmers on climate change.

A nonuniform difference in the trend of the total seasonal precipitations was determined among the meteorological stations (Table 1). The insignificant downward (9 times) and insignificant upward (7 times) trends were obtained for each seasonal data of the stations. Thus, the results of the analysis documented decreasing trends that were determined to be almost insignificant for all seasons. The highest number of insignificant decreasing trends were obtained for winter (4 times over 4), then for spring (2 times) and autumn (2 times), with the average decrease of 83 mm 61 years^{-1}, 13 mm 61 years^{-1}, increase of 13 mm 61 years^{-1} respectively. Approximately, no changes have been detected for the summer during the last 61 years from the monitored

Table 1 - The results of the MK and Sen's slope estimates for seasonal mean temperature, rainfall and relative humidity.

Meteorological Station	*Significance of MK for Seasons*	*Average Temperature Sen's Slope Estimate (°C 60 years^{-1})*			
	A-W-Sp-S	A	W	Sp	S
Mersin	▲▲▲▲	3.7	2.5	2.8	3.2
Erdemli	▲△▲▲	0.8	0.2	0.8	1.5
Silifke	▲△▲▲	1.1	0.9	1.3	1.9
Anamur	▲▲▲▲	2.0	0.7	1.1	2.1
	Average Change	1.9	1.1	1.5	2.2
		Rainfall Sen's Slope Estimate (mm 60 years-1)			
Mersin	△▽△△	38	-46	18	8
Erdemli	▽▽▽▽	-17	-28	-35	-2
Silifke	△▽△△	44	-77	6	0.5
Anamur	▽▽▽△	-14	-182	-42	0.5
	Average Change	13	-83	-13	2
		Relative Humidity Sen's Slope Estimate (% 60 years-1)			
Mersin	▼▼▼▼	-19.1	-17.0	-14.8	-8.7
Erdemli	▼▽▼▼	-7.5	-4.8	-5.7	-4.4
Silifke	▼▽▼▽	-8.4	-5.9	-6.2	-4.5
Anamur	▽▽△△	-3.8	-3.8	0.7	3.6
	Average Change	-9.7	-7.8	-6.5	-3.5

Note: Upward (△) and downward (▽) pointing open triangles indicate insignificant increasing and decreasing trends at the 5% level, respectively. Trends significant at the 5% level ($-1.96 \geq Z \geq +1.96$) are marked by solid triangles (▲ or ▼). W, Winter; Sp, Spring; S, Summer; A, Autumn.

climate data. Similarly, Tayanç *et al.* (2009), observed a marked number of insignificant decreases in the station-based precipitations. Annually, the average total rainfall decreased by 81 mm 61 years^{-1} in our study area. Decreasing trends in precipitations were also recorded in some recent climatic studies undertaken in Turkey for the subject area (Fujihara *et al.,* 2008; Diaz and Topçu, 2010). Moreover, similar results were obtained in different parts of Europe, like in Italy, where it was documented that the total precipitations in the 20th century had decreased by about 5% in the north and by about 15% in the south of the country (Buffoni *et al*., 1999; Brunetti *et al.*, 2001).

In addition to all this, the significant downward (9 times) and insignificant downward (5 times) as well as the insignificant upward (1 times) trends were obtained for each season and station reflecting the dominant decreasing of relative humidity trends of the study area (Table 1). The highest decreasing trends were obtained for autumn (9.5%) followed by winter (7.8%), spring (6.5%) and summer (3.5%). The results of the current study are in line with the study of Kousari and Zarch (2011), which indicates that there has been a definite decrease in the relative humidity in a range of 2.18 to 6.85% in Iran from 1955 to 2000. According to the results of our study, it is clear that there is a negative correlation between relative humidity and air temperature, which was expected.

Consequently, the data reflects that climate is changing in the study area. In particular, the farmers' perception is critical for assisting policy makers in developing proactive precautions within the scope of the fight against climate change.

3.2. *Characteristics of farmers*

Farm size ranged from 0.1 ha to 624 ha, and the average farm size was 7.55 ha in the area under research. 4% of the total surveyed farmers (n: 10) were female and the other 96% were male (n: 241). The farmers' ages ranged from 21 years to 87 years and the average age was 48.62 years (SD: 11.18). The average family size of the surveyed farmers was of 4.4 people (SD: 1.33). The education level of the farmers was generally low. 59.80% of the farmers had attained primary school education, 22.30% had attained secondary school education, 16.30% were university graduates and 1.60% had obtained a master's degree. Farmers' agricultural experiences ranged from 1 year to 75 years and average experience in agriculture was of 26.48 years (SD: 14.83). 43.03% of farmers (n: 108) had an off-farm income source, but the remaining 56.97% (n: 143) had not. 41.48% of the farmers (n: 105) kept physical and financial records of the agricultural production process, but the remaining 58.27% (n: 146) did not. 53.78% of farmers (n: 135) were supported by extension services about the agricultural production process, but the other 46.22% (n: 116) was not. 33.07% of farmers (n: 83) were a partner of an agricultural cooperative, the remaining 66.93% (n: 168) were not. 68.92% of farmers (n: 173) did not get a soil analysis, but the other 31.08% (n: 78) did.

3.3. *Farmers' climate change perceptions*

Farmers' climate change perception investigated using a scale consisted of 14 items. The scores given by the farmers to the items on the scale of climate change perception were over 3.80. So, it can be said that farmers' perception of climate change was quite strong. Also, the standard deviation of 12 out of 14 items was below 1.00. This indicates that there was a general consensus on farmers' perception of climate change. Factor analysis was used to reduce the items in a smaller number of common factors. Factor analysis exacted 2 factors with eigenvalues greater than 1. The two factors extracted from factor analysis explained 61.175% of the total variation. The first factor explained 30.74% of the total variation and consisted of eight items, and the second factor explained 30.435% of the total variation and consisted of six items (Table 2).

In the research area, according to the farmers' perception, the most important issues linked to the impact of climate change is the possibility of the increase in agricultural production costs and the possibility of decrease in the yield of cultivated field crops and vegetables. This finding confirmed the finding of Ndamani and Watanabe (2017). As a matter of fact, as a result of climate

Table 2 - Climate change perception scale's items and the result of factor analysis.

*Items**	*Component*		*Mean*	*SD*
	1	*2*		
CC will lead to an increase in agricultural production costs	0.401	**0.574**	4.34	0.82
CC will cause an increase in weather events such as droughts, floods, and storms, etc.	0.121	**0.832**	4.18	0.89
CC will cause an increase in plant diseases and pests	**0.648**	0.478	4.17	0.86
CC will cause a decrease in the yield of cultivated field crops and vegetables	0.321	**0.780**	4.16	0.90
CC will cause an increase in soil erosion	0.385	**0.673**	4.12	0.82
CC will lead to a reduction in the amount of agricultural land	**0.560**	0.551	4.09	0.92
CC will adversely affect food security	**0.617**	0.449	4.05	0.96
CC will cause a decrease in both cultivated and wild plant species	0.315	**0.741**	4.03	0.92
CC will lead to a reduction in animal species	**0.587**	0.553	4.03	0.88
Migration from rural to urban areas will accelerate in the future due to CC	**0.611**	0.298	4.02	0.95
CC will cause a reduction in soil fertility	**0.787**	0.267	3.99	1.01
CC will cause an increase in human diseases and deaths in the future	0.421	0.576	3.97	0.94
CC will cause an increase in air temperature	**0.690**	0.245	3.96	0.97
CC will lead to a reduction in forest areas	**0.820**	0.194	3.84	1.01
Cronbach's alpha	0.920	0.868	-	-
% Explained variance	30.740	30.435	-	-
% Cumulative variance	30.740	61.175	-	-

*Note: *1: Strongly Disagree, 2: Disagree, 3: Moderately Agree, 4: Agree, 5: Strongly Agree.*

change, it is predicted that agricultural production costs will increase and the yield of agricultural products will decrease especially in regions with a temperate and semi-arid climate. Koç and Uzmay (2019) reported that climate change will lead to a 10-50% increase in costs for dairy farms by the year 2044.

The present study pointed out that surveyed farmers believed that there is a correlation between climate change and weather events such as droughts, floods, and storms. They showed a very strong perception of the "Climate change will cause an increase in weather events such as droughts, floods, storms, etc." indicator. Extreme weather events occur in many regions, even in regions where climate change is relatively perceived less strongly. Therefore, it is difficult to attribute extreme weather events to a specific phenomenon resulting from climate change (Hirabayashi *et al.*, 2013). But some scientific research express that any changing climate may be the reason for the changes in the frequency, intensity, spatial extent, duration, and timing of extremes, and can result in unprecedented weather events (Seneviratne *et al.*, 2012). In parallel with our finding, farmers believed that extreme weather events will increase as a result of climate change in both developing economies (Hameso, 2017) and in developed economies (Lane *et al*., 2017).

Some important effects of climate change may involve plant diseases and damages. The possible effects of climate change are predicted three ways; (1) increased economic losses due to diseases, (2) changes in the efficiency of disease management strategies or (3) changes in the geographical distribution of plant diseases (Chakraborty *et al*., 2000). A research on the change in some abiotic conditions (temperature, CO^2 and ozone concentration, precipitations, and drought) on the biology of pathogens and their ability to infect plants showed that changing abiotic conditions will affect the microclimate regulating plants and the susceptibility of plants to infection (Elad and Pertot, 2014). In parallel with the aforementioned research result, farmers believe that plant diseases and pests will increase due to climate change in Mersin. This finding is in line with Akhtar *et al*. (2018).

Farmers believe that soil erosion will accelerate and soil fertility will decrease due to climate change in the area under research. Farmers also believe that there will be reductions in both the amount of agricultural land and forest areas. Some scientific studies and projections about the effects of climate change on soil erosion, soil fertility and agricultural and forest areas support these views of farmers (Chmielewski *et al*., 2004; Nakicenovic *et al*., 2000).

According to FAO (2008), all the four dimensions of food security (food availability, food accessibility, food utilization, and food systems stability) will be adversely affected by climate change (FAO, 2008). In particular, water scarcity due to climate change will adversely affect agricultural production (Hanjra and Qureshi, 2010). In keeping with decreasing production, food availability and accessibility will be adversely affected. Climatic fluctuations as a result of climate change will also cause fluctuations in food production systems and this will adversely affect the food systems' stability (Schmidhuber and Tubiello, 2007). Farmers in the area under research area also agree that climate change will adversely affect food security. This research finding is supported by Polat and Dellal (2016) and Ahmed *et al*. (2013).

Today's biodiversity is an outcome of the evolutionary process; it is a natural event for some species to disappear and for some species to develop during this process. However, especially in the last century, the extinction of species has been the result of climate change that is caused by human influences and changing production and consumption patterns (Araújo and Rahbek, 2006). In addition, climate change leads to changes in the phonological structure of both flowering plants and pollinating insects, causing a mismatch between plants and pollinators. Then, these impacts cause both plants and pollinators to disappear (Bellard *et al.*, 2012). According to the results of the present study, it can be said that farmers in the area under study believe that climate change will adversely affect both plants and animals' species and reduce biodiversity in the area under research. Similarly, Lorenzoni *et al*. (2007) reported that farmers perceived that climate change would harm other animal and plant species.

3.4. *Determinants of farmers' CC perceptions*

In this section, we run a regression analysis to determine factors affecting farmers' climate change perception. Independent variables and the results of the regression model were presented in Table 3. According to the results, two models were significant. Education, extension and cooperative variables were significant in the first model; experience and cooperative variables were significant in the second model.

In contrast to our expectation, the education level had a negative coefficient in the first model. This implies that more educated farmers perceived less important climate change indicators related to component 1. This finding contradicted with Ndamani and Watanabe (2017). More educated farmers have the ability to better forecast and understand possible changes for the future compared to other colleagues. In the area under research, while the education levels of the farmers increased, the degree of importance they placed regarding the possible negative consequences of climate change de-

Table 3 - Independent variables and the results of regression analysis.

Independent Variables	*Definition*	*Min.*	*Max.*	*Mean*	*SD*	*Results of regression model*	
						C1	*C2*
Constant						-0.342	0.539*
Age	Farmers' age in years	21	87	48.62	11.18	0.012	-0.026
Education	Farmers' level of education; 1: Elementary School, 2: High School, 3: Undergraduate, 4: Postgraduate	1	4	1.6	0.82	-0.236**	0.117
Family size	Number of members	1	9	4.3	1.33	0.041	-0.014
Experience	Farmers' agricultural experience in years	1	75	26.48	14.83	-0.008	0.018**
Off-farm income	If farmers had a source of off-farm income 1; other 0	0	1	0.43	0.5	0.129	-0.063
Record-keeping	If farmers kept physical and financial records of the production process 1; other 0	0	1	0.42	0.49	-0.138	-0.024
Extension	If farmers were supported by extension service 1; other 0	0	1	0.54	0.5	0.101	0.559*
Cooperative	If farmers were a partner of an agricultural cooperative 1; other 0	0	1	0.33	0.47	0.278**	-0.314**
Soil test	If the farmers had a soil test 1; other 0	0	1	0.31	0.46	0.013	-0.129
Farmland	Total farmland as ha	0.1	624	7.55	40.19	0.002	-0.001
Adjusted R Square						0.074**	0.054**

*Note: Variables and models significant at *p < 0.10, **p < 0.05, ***p < 0.01.*

Table 4 - Farmers' climate change perceptions in terms of education (Component 1).

Education	*n*	*Mean**	*SD**
Elementary School	150	4.08	0.76
High School	56	3.99	0.68
Undergraduate	41	3.83	0.66
Postgraduate	4	3.72	0.33
Total	251	3.91	0.61

*Note: *1: Strongly Disagree, 2: Disagree, 3: Moderately Agree, 4: Agree, 5: Strongly Agree.*

creased (Table 4). This may be the consequence of the prediction of more educated farmers that the harmful effects of climate change can be mitigated by developing technology and by improving production and consumption systems in accordance with nature.

Another significant variable was cooperative which had positive coefficient in the first model. Public and private cooperation can play a significant role in providing farmers with the necessary information, education and technologies (Alrusheidat *et al*., 206). This stated that farmers who were cooperative partners perceived more important climate change indicators related to component 1. According to the results of the second model, the variables of farmers' cooperative partnership had significant effects on the per-

Table 5 - Farmers' climate change perceptions in terms of cooperative partnerships.

Cooperative Partnerships	*n*	*Component 1*		*Component 2*	
		*Mean**	*SD**	*Mean**	*SD**
Yes	83	4.10	0.63	4.15	0.64
No	168	3.97	0.76	4.13	0.71
Total	251	4.04	0.70	4.14	0.68

*Note: *1: Strongly Disagree, 2: Disagree, 3: Moderately Agree, 4: Agree, 5: Strongly Agree.*

ceptions of farmers on climate change. Farmers, who are cooperative partners in the region under research, have higher perceptions about the items related to component 1 compared to other colleagues; their perception of items related to component 2 is lower (Table 5).

The positive coefficient for experience of farmers indicates that the more experienced they were, they more concern they expressed about climate change indicators related to component 2. The results are consistent with findings on farmers' climate change risk perceptions in India that showed that farming experience significantly affected farmers' climate change risk perception (Moghariya and Smardon, 2014). Obtaining information and enhancing knowledge about climate change from the extension services play an important role in improving farmers' climate change perception (Maddison, 2007). In accordance with the previous study, it was found that farmers' climate change perception was significantly affected by the availability of extension services in Mersin.

4. Conclusions

This research reflects on the fact that climate is changing in the area under study. In particular, the farmers' perception is critical in assisting policy makers in developing proactive precautions within the scope of the fight against climate change. The research results showed that the farmers had a favorable perception of climate change in Mersin. The study showed that farmers were highly aware of the economic and ecological risks that may arise due to climate change. They were worried about the negative effects of climate change on human and animal health. The result of the regression analysis indicated that some variables affecting farmers' perception. The results of the study showed that farmers have a positive attitude towards implementing measures to reduce the negative effects of climate change. Finally, it can be said that the study investigated the farmers' perception of climate change, but did not investigate whether farmers adopted appropriate practices to reduce climate change risks. Hence, further research should be conducted to find out whether farmers are likely to do so or if they already have.

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Aggregate supply response in Algerian agriculture: The Error Correction Model applied to selected crops

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DOI: 10.30682/nm2101f

JEL codes: Q11, Q18

Abstract

This paper examines aggregate supply response of 19 selected crops in Algerian agriculture during the 1966-2018 period by employing cointegration analysis and Error Correction Model (ECM). It tests whether there has been a long-run equilibrium relationship between agricultural outputs and prices, besides a confirmation about the responsiveness of agricultural supply to economic incentives (prices). Findings indicate that the long-run elasticities of all selected crops with respect to prices are statistically significant and mostly low, whereas short-run elasticities are lower, which appeals to the adequacy of adjustment to economic incentives. Furthermore, the results of the ECM confirmed the positive responsiveness to prices with differential rates of adjustment for selected crops, ruling out the applicability of a presumed perverse supply response in Algerian agriculture.

Keywords: *Aggregate supply response, Crops, Price, Cointegration, ECM, Algeria.*

1. Introduction

Over the past fifty years, the agricultural sector has played a changing role in the Algerian economy. As a result, agricultural production has been strongly influenced through pricing and subsidy policies which have not achieved the expected results. It turns out that the poor performance recorded over such long run period is due to the alteration of the incentive structures of agricultural production. The more interesting aspect, in the context of Mediterranean agriculture, is that price volatility affects the food security (Lacirignola *et al*., 2015) and harms the performances of poor small farmers. Therefore, a detailed and in-depth examination of the agricultural supply in Algerian agriculture is needed. In order to do so, supply response modeling is a tool largely used to evaluate the effectiveness and success of pricing policies regarding farm resources allocation, the role of the agricultural sector, and provides insightful assessments for formulation of economic policy in agricultural production sector.

To the extent that studies on agricultural supply response are almost absent in Algeria, this study is an attempt to examine the responsiveness of Algerian agricultural production to changes in economic incentives during 1966-2018 period (by taking into account the non-stationarity of time series involved in estimation). However, the aim of the study is to test whether there is a

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cointegrated relationship between some selected crops production and their own prices, by using the Error Correction Model (ECM) approach – as the more general approach in modeling agricultural supply response than the extensively used Nerlovian partial adjustment model approach. In other words, do Algerian farmers respond normally to economic incentives (prices)?

Insofar as there are no recent studies which answer this question in the Algerian context, economic theory offers a set of hypotheses which have been submitted repeatedly to empirical verification around the world. In developing countries, the hypothesis that has been approved by earlier empirical studies claims the perverse effect of farmers towards economic incentives[1] (or at least non-response at all). The proponents of this hypothesis were not completely wrong. It turns out that they neglected the environment and the economic system in which farmers live. As concluded by Ghafouri (1988), as the only study of the agricultural supply response in Algeria, the institutional subset of constraints can be summarized in market imperfections that would prevent the underdeveloped agriculture from exhibiting a significant response to price changes.

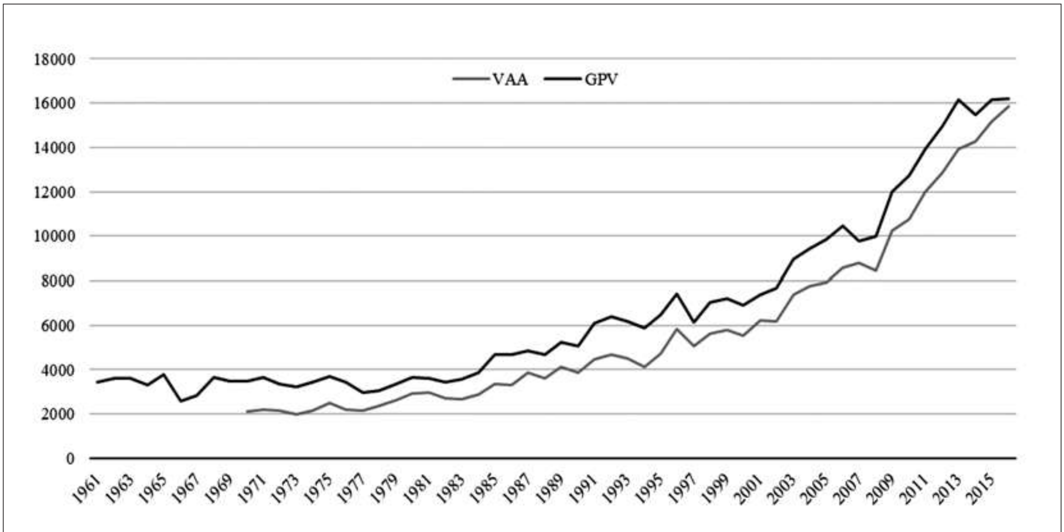
This study uses a sophisticated methodology (a cointegration analysis followed by an ECM) on official data (provided from the FAO) to confirm that Algerian farmers do respond significantly or at least becomes more responsive to economic incentives.

The paper is organized as follows. Section 2 presents briefly the study context and the research hypothesis for the subject of agricultural supply response. Section 3 explores the research methodology and the ECM approach. Section 4 reports and discuss the main results of the study. Section 5 concludes.

2. Agricultural supply response: study context and hypothesis

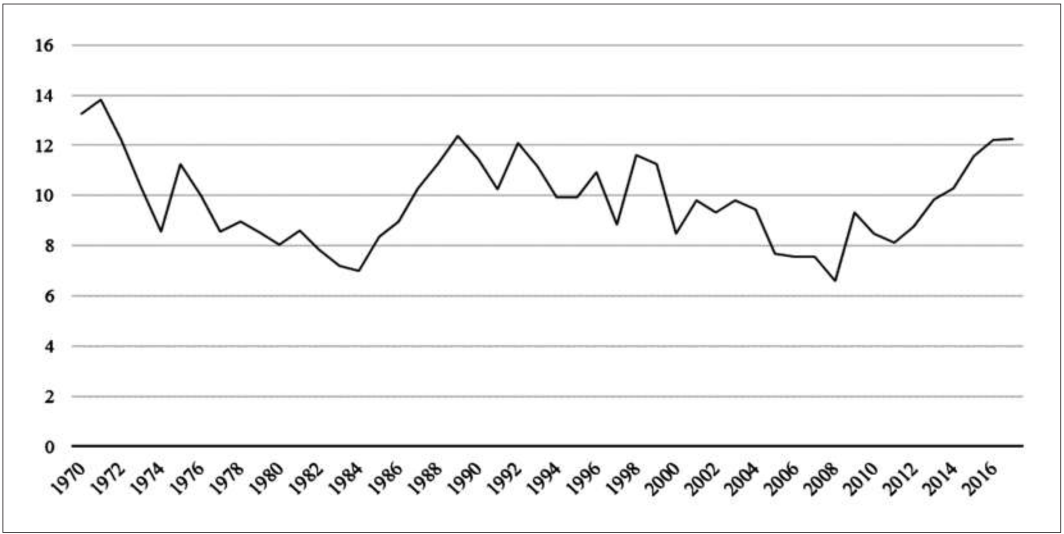
One of the salient features of the Algerian agriculture is its relative importance in terms of the positive trend of the gross production value (reaching 16220 million constant USD in 2018) along with its value added as shown in Figure 1. On the other hand, the share of value add-

Figure 1 - The evolution of the value added and the gross production value of agriculture in constant 2005 million US$ (FAO statistical database, 2020).



[1] For the arguments in favor of this hypothesis, see Ozanne, 1999.

Figure 2 - The evolution of the share of value added of agriculture in GDP of Algeria (FAO statistical database, 2020).



ed of agriculture in the GDP displays no trend (Figure 2). Nevertheless, the contribution of the agricultural sector shows a net decline in the socialist regime environment (until 1984), a net increase in the beginning of the transitional regime (1984 to 1991), another decline until 2008 (where Algeria spent the highly unstable political decade and its consequences), and recently the agricultural sector regain its importance with increasing share.

Therefore, with this sketch in mind, the agricultural supply response in Algeria, since the independence (1962) until now, has been limited mainly by structural and institutional constraints that have persisted despite the many reforms (as well climatic factors are also crucial determinants of the supply).[2] The study of Ghafouri (1988) should by highlighted here. His study covers twelve-year period (1972-84) and applying the Nerlovian model on four agricultural products, namely: citrus, grapes, cereal production and gardening products. His empirical results were unsatisfactory, in his words "not even worthy to report". Ghafouri's study concluded firmly that Algerian farmers do not respond rationally to economic incentives (mainly prices). He explains this by the fact that farmers in that period subsist in a socialist sector completely centralized which prevent the freedom of choices. The implication from this experience is that the underlying model is not an adequate one for the context of developing countries. To understand the Nerlovian model and its underlying hypotheses, a brief sketch on the theory of supply response would be helpful.

One of the basics of economic theory states that there is a positive relationship between the price and the quantity supplied, and implying that farmers respond equally to price changes. The existence of this positive relationship is based on the well-established behavioral assumption of profit maximization of economic agents. In order to confirm that, agricultural supply response studies widely use the Nerlovian model that has been applied in most developed and developing countries.[3] This model, called

[2] Whereas, this aspect is not included in this study. See Bozzola *et al.*, 2018; Migliore *et al.*, 2019 and Chavas *et al.*, 2019 for the Mediterranean context.

[3] For a critical review in LDCs, see: Binswanger, 1989; Schiff & Montenegro, 1997; Ozanne, 1999; Thiele, 2000 and Kumar, 2017.

the partial adjustment model, could be written under a simple specification as follows:

$$Q_t = \beta_0 + \beta_1 P_{t-1} + \beta_2 Q_{t-1} + \beta_3 Z_t$$

where Q stands for agricultural output, P for price, Z for other factors. The subscript t for current period and $t-1$ for the previous period. As the variables are taken in logarithms, the estimated coefficients, β_i are interpreted as elasticities. Particularly, β_1 as the short-run elasticity, and $\beta_1/(1-\beta_2)$ as the long-run elasticity. This model is estimated from variables measured in levels by an OLS estimation with non-stationary data which yields spurious regressions (Granger & Newbold, 1974; Johansen, 1988). Therefore, the results yielded a conflicting evidence ranging from perverse effects to low price elasticity to lack of responsiveness at all, depending on the country, region, crop and aggregation level.

This study is motivated by using more elaborated model of supply response estimation in order to test a general hypothesis as raised by Thiele (2000) from the study of Krueger *et al.* (1992) which stipulates that: appropriate (direct and indirect) price incentives alone encourage agricultural development. Moreover, this study uses a commodity level analysis which gained more emphasis instead of more aggregated measures incorporating change in total agricultural output at country level, or even global such as Hendricks *et al.* (2018), which are less frequently seen in the empirical literature (Ozkan *et al.*, 2011). Besides the fact that aggregate models are superior to the micro-model in predicting acreage response (Wu & Adams, 2002).

3. Research methodology

3.1. *Data source and crops choice*

The used data was obtained fully from the Food and Agriculture Organization's statistical database (FAO).[4] Two variables of interest were selected for the subject of this study: cropped area[5] and crop price. The area is measured by 1000 hectares and producer prices in 10000 LCU per ton for the easiness seek. The data were converted to logarithms in order to easily interpret coefficients of interest as elasticities. Hence, the database has a time series structure, which for both variables, begins in 1966 and ends in 2018.

The procedure of crops selection is as follows: all data on crop areas were selected on the FAO database (167 crops). The results show that only 56 crops were available for Algeria. From this crops set, only 44 crops have the corresponding prices (annual producer prices). In order to maintain only the full-length time or at least recent records, it was found that 22 crops have historical data, i.e., series interrupted in the 90s (typically: 1966-1990, 1966-1995, etc.). In the remaining 22 crops, the three existing cereals (wheat, barley and oat) were dismissed from the set due to certain considerations of direct price intervention policy envisaged by the Algerian government. As a result, we get the final database of 19 crops including 8 fruits (apple, date, grape, lemon, mandarin, melon, orange and pear) and 9 vegetables (carrot, cauliflower, chili pepper, garlic, bulb onion, scallion, potato, pumpkin and tomato) and 2 pulses (green bean and pea). Table 1 represents the per mille shares of each selected crop in the total cropland area in the corresponding three years (1966, 2002 and 2018), along with the time intervals.

Table 1 shows the relative importance of the selected crops with respect to the year-corresponding cropland area in Algerian agriculture. All crops show an increasing importance, except for grape and mandarin, and for some extent orange crops. More particularly, grape was the only major crop in Algerian agriculture, whereas its importance has been declined gradually (from 49.41‰ in 1966 to 8.19‰ in 2018). Moreover, most recently (in 2018) and due to the changes in food consumption pattern of Algerian population, it seems that date and potato crops are the most important crops in

[4] FAO official website: http://www.fao.org/faostat/en/#data.

[5] As initiated by Nerlove (1956; 1958), the traditional approach to supply response for individual agricultural commodities involves the use of planted or harvested acreage to represent planned output (Seale *et al.*, 2013).

Table 1 - The shares of cropland area for each selected crop.

Crops	*Time Interval*	*Shares (‰) in the total cropland area*		
		1966	*2002*	*2018*
Apple	1966-2018	0.36	1.85	4.60
Date	1966-2018	6.78	14.72	19.93
Grape	1966-2018	49.41	6.60	8.19
Lemon	1966-2018	0.22	0.34	0.53
Mandarin	1966-2018	2.06	1.49	1.83
Melon	1966-2018	2.54	3.55	7.13
Orange	1966-2018	6.19	3.43	6.00
Pear	1966-2018	0.28	1.45	2.66
Bean	1966-2018	0.23	0.78	1.37
Carrot	1966-2018	0.59	2.47	2.11
Cauliflower	2001-2018	/	0.47	0.95
Chili Pepper	2002-2018	/	1.99	2.61
Garlic	1987-2018	/	1.09	1.52
Onion (bulb)	1966-2018	1.04	3.61	5.58
Onion (Scallion)	1995-2018	/	0.03	0.04
Pea	1966-2018	0.61	0.86	1.22
Potato	1966-2018	3.75	8.84	17.67
Pumpkin	2002-2018	/	0.99	1.59
Tomato	1966-2018	1.08	2.17	2.63

Algeria (with shares of 19.93‰ and 17.67‰ respectively). In general, all crops display a significant relative importance in Algerian farming system. In terms of the time interval, almost all crops have a full-length interval (i.e., 52 years), which is a very long time length for any analysis, except for cauliflower, chili, garlic, scallion and pumpkin, representing shorter time lengths (from 16 to 31 years), which is also long enough.

3.2. *Estimation method: The ECM approach to supply response*

The Nerlovian partial adjustment model has been the dominant method used in modeling the supply response during the last decades of the 20th century. It was based on the minimization of a single period loss function L of the form: $L_t = \lambda_1 (Y_t - Y_t^*)^2 + \lambda_2 (Y_t - Y_{t-1}^*)^2$ for a given level of a variable, Y. The results yield the partial adjustment model with a coefficient of adjustment $\lambda = \lambda_1 / \lambda_2$. The model assumes that there is an equilibrium toward which producers are moving in the long-run and determined on the basis of a static theory of optimization (static expectations),[6] which assumes that future values of the exogenous variables (mainly prices) remain unchanged (Weliwita & Govindasamy, 1997). By using a more general intertemporal quadratic loss function, Nichell (1985), Hallam & Zano-

[6] As criticized by Nerlove himself (1958; 1979). For a detailed review, see: Askari & Cummings, 1977, chapter 4; Hallam & Zanoli, 1993 and more recently Seale *et al*. (2013).

li (1993) and Johansen (1988; 1995) developed more realistic and dynamical adjustment model, which results in the use of "the Error Correction Model". Therefore, the Error Correction Model has become a more general approach to modeling agricultural supply response than the commonly used Nerlove partial adjustment model, particularly the last two decades.

The modeling procedure begins with establishing the long-run equilibrium relationship between *y* (cropped area as a proxy of the agricultural output) and *x* (producer price) as expressed by the following formula:

$$y_t = \beta x_t + \varepsilon_t \qquad [1]$$

Thus, the simplest form of the error correction model can be written as following:

$$\Delta y_t = \delta \Delta x_t - \lambda \varepsilon_{t-1} + \omega_t \qquad [2]$$

where ω_t is a disturbance with mean zero, constant variance, and zero covariance. δ measures the short-run effect on *y* of changes in *x*. ε_{t-1} measures the errors which corresponds to the residuals of a lagged version of long-run equilibrium relationship (equation [1]). λ measures the extent of correction of these errors by adjustments in *y*, the negative sign showing that adjustments are made towards restoring the long-run relationship, and the short-run adjustments are therefore guided by, and consistent with, the long-run equilibrium relationship (Hallam & Zanoli, 1993). For the correctness of the ECM procedure, values of λ should be negative, between 0 and 1, and also statistically significant. The ECM approach can be interpreted as describing farmers reacting to moving targets and optimizing their objective function under dynamic conditions (McKay *et al.*, 1999; Olubode-Awosola *et al.*, 2006). Before running the modeling procedure, a cointegration analysis should be performed according to the "Granger representation theorem". This theorem points out that where variables are cointegrated, I (1), there exists a valid Error Correction Model describing their relationship (Engle & Granger, 1987; Apostolopoulos & Stoforos, 1995), with the implication that co-integration between the variables involved is a prerequisite for the Error Correction Model (Hallam & Zanoli, 1993; Seale *et al.*, 2013).

4. Results and discussion

This section presents the findings on the aggregate supply response patterns in Algeria, showing the responsiveness of the selected crops to varying changes in the prices changes covering mostly the period from 1966 to 2018. Therefore, the section contains empirical results of cointegration analysis that addresses the patterns of supply and main estimation results of 38 regressions for the supply functions of the selected crops.

Results of the Augmented Dickey-Fuller (ADF) and cointegration analysis are shown in Table 2. The first column represents the selected crops. In order to test for non-stationarity of economic series included in regression models as to avoid the spurious regressions, this study conducted the ADF unit root tests of each variable in the study. The test was performed on the levels with constant (without trend term) using 4 lag order and *t*-statistic criterion. The results are summarized in column 2 for both areas (*y*) and prices (*x*) for each crop. Values in parentheses represent their respective *t*-ratios. Essentially all the series in cropped areas and crop prices were associated with *t* statistic that is greater than the critical value for the rejection of unit root for each ADF test. Thus, the series are not stationary, i.e., the null hypothesis of non-stationarity for the 38 variables was accepted. The significant and important evidence from the ADF unit root tests relates to the presence of non-stationary series in both area and price variables for the 19 crops.

For any meaningful long-run relationship to exist between the two non-stationary series (areas and prices), it is imperative that some linear combinations of the series must be co-integrated. More particularly, they must follow a common trend which permits a stable long-run relationship for both. If cointegration is statistically confirmed, a non-spurious long-run equilibrium relationship exists. Thus, this study conducted both Engle–Granger and Johansen cointegration

Table 2 - The ADF and cointegration tests for the selected crops in Algerian agriculture.

Crops	*Augmented DF Test*	*Engle–Granger Test*	*Johansen Test*	
			Eigenvalue Test	*Trace Test*
Fruits				
Apple	*y* –0.136 (–2.14) *x* –0.012 (–1.09)	–0.164 (–2.32)	0 0.236 1 0.003	14.222 (0.022) 0.187 (0.736)
Date	y –0.137 (–2.01) *x* –0.136 (–3.27)	–0.086 (–1.50)	0 0.411 1 0.001	27.574 (0.003) 0.0014 (0.969)
Grape	y –0.017 (–0.77) *x* –0.010 (–0.13)	–0.065 (–2.14)	0 0.386 1 0.004	25.442 (0.009) 0.022 (0.880)
Lemon	*y* –0.138 (–2.41) *x* –0.226 (–2.66)	–0.146 (–1.80)	0 0.136 1 0.053	10.475 (0.250) 2.8521 (0.091)
Mandarin	*y* –0.049 (–0.41) *x* –0.005 (–0.62)	–0.104 (–1.19)	0 0.261 1 0.052	18.605 (0.015) 2.8132 (0.093)
Melon	*y* –0.142 (–1.78) *x* –0.145 (–2.14)	–0.148 (–2.06)	0 0.134 1 0.001	7.584 (0.517) 0.060 (0.805)
Orange	*y* –0.015 (–0.36) *x* –0.010 (–0.16)	–0.044 (–1.10)	0 0.090 1 0.001	5.056 (0.801) 0.095 (0.757)
Pear	*y* –0.172 (–2.28) *x* –0.008 (–0.55)	–0.158 (–1.54)	0 0.112 1 0.003	6.197 (0.676) 0.003 (0.951)
Vegetables and pulses				
Bean	y –0.104 (–1.09) x –0.031 (–0.96)	–0.267 (–3.04)	0 0.292 1 0.066	21.555 (0.004) 3.595 (0.057)
Carrot	y –0.139 (–1.60) x –0.087 (–1.20)	–0.084 (–1.36)	0 0.094 1 0.014	5.953 (0.703) 0.770 (0.380)
Cauliflower	y –0.971 (–1.81) x –1.299 (–2.34)	–0.827 (–3.41)	0 0.443 1 0.005	9.971 (0.288) 0.005 (0.982)
Chili Pepper	y –0.435 (–2.59) x –0.382 (–1.58)	–0.609 (–3.13)	0 0.567 1 0.153	16.096 (0.038) 2.670 (0.102)
Garlic	y –0.585 (–3.49) x –0.934 (–4.53)	–0.294 (–2.06)	0 0.194 1 0.006	6.710 (0.617) 0.019 (0.887)
Onion (bulb)	y –0.245 (–2.78) x –0.297 (–2.38)	–0.393 (–2.79)	0 0.305 1 0.001	18.977 (0.012) 0.001 (0.991)
Onion (Scallion)	y –0.381 (–2.14) x –0.709 (–1.52)	–0.666 (–3.36)	0 0.396 1 0.040	12.561 (0.132) 0.944 (0.331)
Pea	y –0.167 (–2.10) x –0.100 (–1.53)	–0.383 (–3.48)	0 0.211 1 0.003	12.539 (0.133) 0.205 (0.650)
Potato	y –0.125 (–1.82) x –0.130 (–1.27)	–0.237 (–2.82)	0 0.153 1 0.002	8.690 (0.401) 0.013 (0.907)
Pumpkin	y –0.671 (–1.01) x –0.984 (–3.48)	–0.656 (–3.01)	0 0.404 1 0.109	10.166 (0.273) 1.861 (0.172)
Tomato	y –0.182 (–2.30) x –0.010 (–0.15)	–0.194 (–2.57)	0 0.118 1 0.003	6.739 (0.613) 0.159 (0.689)

Note: Values in parentheses are: for the ADF and Engle–Granger tests, represent the t-statistic, and for the Johansen test, they represent the p-values for the test.

tests for the linear combination of the series for the selected crops. The Engle–Granger is known as a residual-based single-equation approach. It assumes that the variables in the long-run equation are all I(1) and tests whether the error term in equation [1] is I(1) against the alternative that it is I(0). Whereas the Johansen reduced-rank approach is a system approach which tests for the existence of a more than one co-integrating relationship using both the Eigenvalue and Trace tests. The two procedures are used together in this study only to support evidence on the long-run equilibrium relationships among variables. The results are summarized in columns 3 and 4 of the Table 2. According to these tests results, both the Engle–Granger and the Johansen tests indicate the existence of co-integrating relationships between planned supply (cropped area) and the price variables.

After long-run relationships between cropped area and the price variables predicting it are confirmed, the ECM could be established. Results are reported in Table 3. The first column represents the selected crops. The long-run regressions results are performed separately and only the values of β were reported in the second columns. The 19 regressions present typically (although necessarily) higher values of R^2 with the presence of autocorrelation (i.e. low values of *DW* statistic). The remained columns display the results of 19 ECM estimations. The models are evaluated on the basis of the following criteria: adjusted coefficient of determination ($\hat{R}^2$), Durbin-Watson statistic (*DW*) and the *F*-statistic for the overall statistical significance. The last column represents the time length (T) until 2018.

According to results from the long-run estimates (β estimates), planned supply of most selected crops are affected positively (with higher statistical significance at 1%) by their own prices. Except for grape, mandarin and orange fruits which display significant negative effects. These findings revealed that the lagged price of most crops had a positive influence on the current crop production. This indicated that the Algerian farmers in general responded positively (i.e. rationally) to the previous year's price to determine the future drift in price. It is noteworthy to mention that among fruit producers, apple growers have the highest long-run elasticities (51.1%). Whereas among vegetable producers, it seems that cauliflower, chili pepper and scallion growers have the highest long-run elasticities (99.2, 56.5 and 63.9% respectively).

The short-run relationship estimation is less worth diagnosing, besides having a low goodness of fit. The short-run elasticities (δ estimates) of most of crops are low with relatively low statistical significance. Except for bulb onion (at 1%), bean, chili, pumpkin crops (at 5%) and grape and cauliflower crops (at 10%). However, the most interesting idea in the interpretation of the results of the ECM is to check the EC term (λ estimates) conditions: its negative value, its absolute value, and its significance. It seems from the coefficient estimates of λ that all values are negative, statistically significant and its values are between 0 and 1. The error correction coefficient indicates a differential feedback of the previous year's disequilibrium from the long-run elasticity of crops price. This implies that the speed with which crops price adjust from the short-run disequilibrium to changes in crop supply in order to attain the long-run equilibrium within one year differs significantly from crop to another. More particularly date, bean, cauliflower, chili and pumpkin crops are the most rapid adjustment rates among all selected crops (respectively 43, 47, 51, 58 and 66.5% for each year). Conversely, grape and orange crops have the lowest rates of price adjustment (respectively 1.6 and 1.3% each year). Curiously, these two fruit crops exhibit abnormal behavior in the long-run price response.[7] The remained fruits have rates between 1 and 24%, while the other vegetables are between 12 and 29%. Nonetheless, these further confirm once again, the existence of the cointegration relationship in the models.

[7] This abnormal behavior perhaps could be due to a misspecification in the long-run supply function, to the extent that these crops have been submitted to some technological advances or intense supply shifts induced on stable demand curves, as they are considered as industrial inputs *par excellence*.

Table 3 - The ECM results (long- and short-run) for the selected crops in Algerian agriculture, 1966-2018.

Crops	*β*	*δ*	*λ*	$\hat{R}^2$	*DW*	*F*	*T*
Fruits							
Apple	0.511 (24.13)***	0.192 (1.64)	−0.157 (−2.22)**	0.135	1.853	3.90**	52
Date	0.199 (20.16)***	0.078 (0.81)	−0.428 (−3.75)***	0.230	1.993	7.48***	52
Grape	−0.241 (−16.27)***	−0.089 (−2.00)*	−0.016 (−3.54)***	0.103	1. 337	2.75*	52
Lemon	0.227 (12.99)***	0.046 (0.65)	−0.160 (−2.56)**	0.155	2.059	3.64**	52
Mandarin	−0.029 (−4.11)***	−0.013 (−0.19)	−0.247 (−2.24)**	0.101	2.373	2.56**	52
Melon	0.171 (12.81)***	0.093 (1.55)	−0.155 (−2.22)**	0.116	1.979	4.49**	52
Orange	−0.267 (−3.25)***	0.010 (0.24)	−0.013 (−1.97)**	0.102	1.677	1.15*	52
Pear	0.438 (23.96)***	0.135 (1.59)	−0.193 (−2.50)**	0.145	1.829	4.25**	52
Vegetables and pulses							
Bean	0.301 (31.87)***	0.182 (2.11)**	−0.479 (−4.46)***	0.316	1.734	11.58***	52
Carrot	0.414 (8.07)***	0.187 (1.21)	−0.192 (−1.94)*	0.146	2.179	1.29	52
Cauliflower	0.992 (8.67)***	0.393 (2.00)*	−0.506 (−2.26)**	0.284	1.911	2.98**	17
Chili Pepper	0.565 (6.80)***	0.353 (2.38)**	−0.580 (−3.10)***	0.502	1.593	7.06***	16
Garlic	0.105 (5.21)***	−0.007 (−0.165)	−0.296 (−2.30)**	0.173	1.399	2.83*	31
Onion (bulb)	0.338 (3.75)***	0.161 (3.10)***	−0.269 (−2.78)***	0.223	2.161	7.20***	52
Onion (Scallion)	0.639 (3.34)***	0.057 (1.64)	−0.244 (−4.74)***	0.133	1.185	1.61	23
Pea	0.323 (3.34)***	−0.052 (−0.33)	−0.198 (−2.30)***	0.102	2.037	2.86*	52
Potato	0.183 (8.13)***	−0.016 (−0.24)	−0.146 (−2.41)**	0.113	1.727	3.19*	52
Pumpkin	0.340 (6.83)***	0.218 (2.64)**	−0.665 (−2.81)**	0.437	2.072	5.44*	16
Tomato	0.065 (1.99)*	−0.190 (−1.36)	−0.125 (−1.97)*	0.133	2.195	3.84*	52

*Note: Values in parentheses represent the t-statistic. *** for significance at 1%, ** for significance at 5%, * for significance at 10%, no asterisks for no significance at all.*

In terms of the sign of long- and short-run elasticities for selected crops of this study, the findings corroborate many results of recent studies. Nevertheless, some of them used slightly different methodologies. However, the common point is the acreage responsiveness to crop prices. Studies with positive response elasticities are as follows: Haiyan & Xuezhong (2017) for apples in China; Wani *et al*. (2015) for apples and pears in Jammu & Kashmir; Gurikar (2011) for onions in India; Seale *et al*. (2013) for oranges, tomatoes and bulb onion in the U.S.; Xu *et al*. (2012) for grapes in China; Mostofa *et al*. (2010) for cauliflower and tomato in Bangladesh; Yao & Zhou (2013) for garlic in China; Vembu *et al*. (2013) and Abraham & Pingali (2019) for several pulses in India; Huq & Arshad (2010) for potato in Bangladesh; Lantican *et al*. (2008) for tomato in Philippines.

5. Conclusion

The paper examined agricultural supply response for Algerian agriculture. Data was taken for the period 1966 to 2018 provided by the FAO statistical database on cropped areas and crop prices, where 19 crops were minutely selected. The paper aimed to investigate the extent that Algerian farmers do respond to economic incentives. Time series analytic techniques (cointegration analysis and Error Correction Model) were used to undermine the quantitative effects of the price of the selected crops production.

The main findings of this study could be summarized as follows. The selected variables were non-stationary (as confirmed by the ADF unit root tests). The bivariate analysis of these two variables (using both Engle–Granger and Johansen procedures) for each crop confirmed the existence of co-integrating relationships between them. The study also indicated that the long-run elasticities with respect to prices are generally low and statistically significant, and the results of the ECM confirmed the positive responsiveness to prices with differential rates of adjustment for all selected crops.

Some useful implications could be derived from this study. As the estimated supply elasticities came out to be less than unity, this means that supply response is price inelastic, whereas they appeared to be high enough to imply that further agricultural reforms are required. Furthermore, to the extent that the aggregate supply of these crops is positively affected by its own producer prices in both the short-run and long-run as established econometrically, these findings rule out the applicability of perverse supply response in Algerian agriculture. Moreover, the findings suggest that farmers tend to increase acreage cultivated in response to economic incentives (namely prices). This implies that farmers have (or at least began to have) more control over land than the other factors that could influence agricultural output. Also, the analysis showed that short-run response in crop production is lower than long-run response. This is because in the short run the farmers are constrained by the access to resources needed to adjust appropriately to economic incentives. In the short-run, inputs are considered as relatively fixed. To address these concerns government should devise policies to make land available to farmers so that prospective farmers could increase acreage cultivated. The findings also suggest that farmers are indeed responsive, which is consistent with the evidence of the positive effects of the pricing policies, launched since the adjustment policies were inaugurated in the 1990s, on the producer's behavior in terms of production choices and performance.

This study pave the path for several research perspectives on the performance of agricultural supply in Algeria despite certain limitations. In our analysis, non-price factors were not considered for the sake of simplicity, despite their crucial importance. Further studies could include those already available, including mainly the effect of the technology level, effect of irrigation facilities, effect of production risks on producers' choices, and even the instability of political regimes in the agricultural sector. Although our analysis has the advantage of being based on a very long time interval (52 years), a sequential analysis on specific and more homogeneous periods could be conducted for each crop separately, especially for the fruit crops that revealed problems of perversity (mainly grape and orange crops). This would be a prosperous task that could provide valuable information in terms of the implementation of adequate incentive structures. However, more in-depth research on the agricultural supply response in Algeria is needed in order to contribute in the design of pricing policies aimed at fostering the growth of the agricultural sector.

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Impact of parcel fragmentation on the calculation of the real estate value of land belonging to farms

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DOI: 10.30682/nm2101g
JEL codes: Q10, Q15, Q18

Abstract

Agricultural parcels are often the subject of land valuation studies. This approach implicitly assumes that the real estate value of the land belonging to a farm is the sum of the values of the individual parcels that make up the farm. Nonetheless, the value of a whole can be very different from the sum of its parts. This study proposes a methodology for calculating the real estate value of the land belonging to a farm, the latter being understood as the set of the parcels, not only on the basis of production factors such as surface area, type of crop and intensity, but also by including parameters relating to the fragmentation of the land. Fragmentation increases production costs and reduces farmers' incomes and by extension the real estate value of the farm. In our study area, the province of Jaen in Spain, figures for its most emblematic crop, the olive, show that fragmentation of the land reduces its value by between 51% for a 10 ha farm and 12% for a 30 ha farm as compared to the values set out in the bibliography. The reorganization of the ownership system or the promotion of systems for the common management of land could increase the profitability and therefore the value of land according to the 'income capitalization' approach.

Keywords: *Farm value, Fragmentation, Income capitalization, GIS.*

1. Introduction

The object of land valuation is to calculate the price of land on the basis of a series of selected criteria. Agricultural land is valued for a range of purposes, both private (loans, division of estates, mortgages, property sales, agrarian insurance policies, etc.) and public (especially in proceedings such as expropriation, organization of farms, consolidation of farm land, assessment of damage caused by the Administration), and for tax reasons (property tax, tax on the sale or transfer of real estate and documented legal acts, etc.). Accurate calculation of the value of land is therefore vital to guarantee legal certainty for the owner and the protection of his or her rights (López de Luis, 2010). A fair land valuation method is therefore essential.

In the procedure for determining the real estate value of rural land, valuers tend to focus on the values of the individual agricultural parcels that make up the farm (Ma and Swinton, 2012), rather than calculating the real estate value of the farm as a whole. Nonetheless, the value of a whole can be very different from the sum of

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its parts. A reliable method for calculating the value of the land belonging to a farm as a whole could therefore be particularly important in processes for the wholesale transformation of agrarian structures, in that it would allow much fairer valuations to be made, by taking into account all the factors that influence the real estate value of land. These processes include for example farm reorganization plans, initiatives proposed by government bodies in which grants are provided for the improvement of agrarian structures in areas in which there is a predominance of small and medium-sized holdings in which a land consolidation process is due to be performed (Maceda Rubio, 2014). Farms may also need to be valued when they are put up for sale, often due to a lack of generational renewal (Jeanneaux *et al.*, 2017).

Various methods have traditionally been used to estimate the real estate value of agricultural land (Wahlen *et al.*, 2013) with highly varying results (Jeanneaux *et al.*, 2017). Different methods are used depending on the objective of the valuation, the type of ownership or the particular land use (Wyatt, 1997). One widely used method is the comparative method (Pagourtzi *et al.*, 2003), in which the value is estimated by analysing the sale prices of comparable unimproved land and then adjusting the prices to account for any differences in size, location, and features. However, this method does not take into account the income generated by the property or other important parameters such as soil type, climate and topography. With this in mind, other land valuation methods using regression analysis were developed in order to consider the impact of specific variables such as economic yield, risk of frost, plantation age or land quality (Calatrava and Cañero, 2000; Maddison, 2000). Other researchers also considered the way the farm had been managed when valuing the land (Eves, 2007). Finally, the use of decision tree analysis in the land valuation process was proposed in order to identify possible sub-samples in the available information on rural estate values that represent specific market segments that were not detectable in the original data set (Acciani *et al.*, 2008).

In order to ensure reliable results, these methods generally require significant amounts of information about recent transactions involving similar estates or properties. However, these methods tend not to be used in the valuation of agricultural land in countries like Spain in which there are relatively few rural land transactions and the market is less transparent than for urban and building land (AEBOE, 2015). This is why in those procedures in which the public administration is involved, the use of the 'income capitalization' method has become mandatory.[1] This method values land on the basis of its suitability for production, in an unlimited scenario which assumes that for the foreseeable future the land will continue to be used for agricultural purposes with the same crop. In this way by calculating the difference between farm revenue and costs, it is possible to calculate the annual return on each parcel being valued. By applying a specific capitalization rate, the real estate value of the land is then obtained.

In order to be able to apply this method correctly, the valuer must know how much income or profit is generated by the lasset he/she is appraising. The most commonly used variable for measuring agrarian income is the area of the land being valued (Cañas *et al.*, 1994; Caballer and Guadalajara, 2005). The analysis of the income from agricultural land also normally involves the valuation of other variables such as economic yield, the quality of the land, the risk of frost and the location (Aznar and Guijarro, 2004; García *et al.*, 2017), which although they influence the profitability of the land are not the only factors affecting it. Other factors that directly affect the profitability of the land and therefore its real estate value are often ignored. For example, Eves (2007) showed that the technical, financial and environmental management of the farm had a direct influence on its value, creating differences in the real estate value of up to 20%.

[1] Royal Decree 1492/2011, of 24th October. Available at: https://www.boe.es/buscar/pdf/2011/BOE-A-2011-17629-consolidado.pdf.

Non-monetary values may also add to the value of the farm, as suggested by Howley (2015). In the same way, the fragmentation and dispersion of the parcels of land that make up a farm have a direct impact on its value, in that these farms are often less efficient and produce smaller returns (Latruffe and Piet, 2014; Colombo and Perujo-Villanueva, 2017a; Perujo-Villanueva and Colombo, 2017; Lu *et al*., 2018). Farms of the same size can have very different costs and therefore profit levels, depending on the number and the shape of the various parcels of land of which they are composed and the distance between them (Tan *et al.*, 2010; Vilar Hernández *et al.*, 2011). These variables often go unnoticed in cost studies used as a reference for calculating the annual income and thus are not considered when estimating the associated real estate value.

In Europe, the extremely fragmented land ownership structure makes it particularly important when valuing land to consider the impact of land fragmentation on farm income. According to EU data, 69% of farms cover less than 5 ha and only 2% have more than 100 ha (European Commission, 2013). In this situation any calculation of the profitability of farms, and by extension the real estate value of the land, must take the impact of these variables into account when calculating the differences in income due to the inefficiency of fragmented farms. Small farms have higher costs that reduce their annual income (Colombo and Perujo-Villanueva, 2017a), in some cases even leading to negative returns, which make the 'income capitalization' method inviable.

In this paper we will be focusing on calculating the impact of the structural aspects of farms, namely farm size and parcel fragmentation and dispersion, on the real estate value of the land at farm level, a question that has yet to be broached in the literature. The objective of this research is to create a tool to enable the public administration and land valuers to adjust the real estate value of farms according to the degree of fragmentation, on the basis of simple variables such as the surface area, the number of plots and the distance between them. This is timely considering that in small farms the cost overruns, caused by the lack of economies of scale in production and by land fragmentation, can lead to situations in which it is impossible to break even. It is therefore necessary to encourage the administration to introduce measures to increase the profitability of farms (land consolidation, tax exemptions, farm reorganization plans). For these measures to be successful, accurate valuations of the real estate value of the farms are required. In this research, we also demonstrate that any public or private action aimed at reducing farm fragmentation not only has a positive short-term effect on the economic viability of the farms involved (Vilar Hernández *et al.*, 2010), but also increases their real estate value and in turn the overall wealth of rural communities, a global goal of the Common Agricultural Policy (CAP) today and for the future. The methodology we propose is applied to traditionally farmed olive groves but could also be used with other crops.

The paper is structured as follows: we begin by defining the rules and laws governing the methods used for the valuation of rural property in Spain; we then describe the study area and set out the methodology we propose for quantifying the value of farms. In the results and discussion section we summarize the main effects and comment on the different comparative scenarios for the valuation of rural properties. We conclude by making clear that the real estate value of the farm can vary considerably according to the impact of the spatial distribution and the shape of the parcels. Small atomized farms have much lower values than their larger, more concentrated counterparts.

2. The valuation of agricultural land in Spain

In Spain today the Amended Text of the Law on Land and Urban Redevelopment (AEBOE, 2011), hereinafter ATLLUR, provides a general framework for the valuation of land for administrative purposes (Falcón-Pérez, 2015) and advocates the use of the 'income capitalisation' method for calculating the value of agricultural land (Art. 36). This method takes into account the capacity of the land for generating future cash flows and determines income on the basis of the productivity of the estate, focusing particularly on its location, on the type of crop and the machinery normally used in its production (Cañero León and Calatrava Requena, 2000), including subsidies of a stable nature and subtracting the costs incurred. The income calculation is based primarily on the consideration of land as a production factor. Specifically, the method is based on calculating the annual income (total revenue minus the costs) and projecting it onto an unlimited scenario based on the useful life of the crop. This means that the value of the agricultural land is affected by the type of crop and by how efficiently it is managed. The final value could be adjusted upwards on the basis of different location factors. In addition, the income capitalisation approach requires the use of an interest rate which, according to the provisions of Additional Clause 7 of the ATLLUR, is determined by a general interest rate multiplied by a corrective coefficient which is published for each type of crop.

The bibliography most critical of this method highlights various aspects: firstly the difficulty of defining the income from each farm, on many occasions resulting in income being calculated as a percentage of final production (Gutiérrez Flores, 2010); secondly the limited availability of cost studies that reflect the real situation of the farm being considered; thirdly, the conditionality involved in using a predetermined interest-rate given that the variability in this rate can have a considerable effect on the real estate value of the property.[2] Fourthly and finally the fact that sociological factors, which at times are more important than the income from the crop, are not taken into account (Jeanneaux *et al.*, 2017).

None of the studies cited above refer to the need to calculate the value of the farm, defined as the group of parcels that make up the land owned by an olive farmer on which he/she carries out his/her farming activities, primarily aimed at the market and which constitutes a technical economic unit in itself. In other words, in the aforementioned studies the object being valued is the individual parcel or plot of land and the methodology does not differentiate the case where the farm as a whole is the object of valuation. Farming research has shown that agrarian systems must be considered as a complex fabric and not as a mere collection of agricultural parcels that influence their configuration (De Juan Valero *et al.*, 2003) and therefore their production methods and efficiency. In addition, if the management of the different parcels is performed with the same machinery and human resources and within a common agronomic, technical organization, the farm as a whole must be considered as the basic technical unit and not as various basic units, or in other words, various separate farms (Ballestero, 2000).

The Draft version of the Andalusia Agriculture and Livestock Act sets out the case for valuations at farm level. Article 31 of this Act states the need to promote farm reorganization plans in order to create farms of sufficient size and characteristics in terms of their structure, capitalization, business organisation and environmental integration.[3] This procedure, known as land consolidation, seeks to improve the structure of land ownership in specific districts or areas, for which purposes it is necessary to calculate the value of the set of plots contributed by each farmer, in order to create more concentrated, less fragmented farms with a similar value to that of the land contributed.

3. Study area

This research focuses on the traditional, machine-workable (gradients of less than 25% accessible to tractors) olive groves in the province of Jaen, Southern Spain, which cover 78.5% of the useful agrarian area. The olive tree is undoubtedly the most emblematic crop in this province, extending over 551,191 ha or 83.3% of its total farmed area. This represents 26% of

[2] The impact of this variability has been attenuated in part by using as the capitalization rate the average value (from the annual data published by the Bank of Spain) for the return on 30-year Government Bonds, for the three years prior to the date to which the valuation is understood to refer (AEBOE, 2015).

[3] Draft version of the Andalusia Agriculture and Livestock Act. Available at: https://www.juntadeandalucia.es/export/drupaljda/normativa_en_elaboracion/16/10/Texto%20vesi%C3%B3n%20pdf.pdf.

the total area planted with olive trees in Spain as a whole and 46% of the olive groves in Andalusia (CES, 2011). In general terms, the agrarian structure of the province, a concept that includes parameters such as ownership and forms of farming and landholding, is characterized by its heterogeneity and/or polarization: there are a large number of small farms and relatively few large ones. As regards fragmentation, the figures indicate that the average farm has 5.3 ha, although 77.6% of them have 5 ha or less (Colombo and Perujo-Villanueva, 2017a). The olive farms in the province have a total of 261,450 plots making an average of 3.1 plots per farm. The most fragmented farm has 101 parcels, though farms with more than 10 parcels make up just 3.4% of the total. As regards the geographical dispersion of the plots, the average value is 4 km. The minimum value is 0 km for 36% of the farms and the maximum is 73.6 km (Perujo-Villanueva and Colombo, 2017). Figure 1 shows a real image of typical olive farm structures in the study area taken from the Spanish Land Parcel Identification System.

Traditional olive farming is showing worrying signs in terms of the return on this crop, especially due to the high fragmentation of ownership, the relatively limited professionalization and modernization of the farms and the high production costs. These low returns mean that many olive farmers depend on subsidies from the CAP and on family labour (Colombo *et al.*, 2016) to break even. The current situation is likely to get worse given the age of the agrarian population in which 74.6% are over 44 years old and 25.3% are over 64 years old (CPJA, 2015) and due to the gradual reduction of support from the CAP. The fact that few members of the younger generation seem interested in farming (Langreo Navarro, 2002), the uncertainties of the Common Agricultural Policy and the low income from olive farming combine to paint an unattractive picture for the future of rural Jaen. The result is that a growing number of small

Figure 1 - Examples of the parcel composition and dispersion of typical olive farms in the study area.

farmers are being forced out of farming every year and their land is being put on the market for sale (Franco and Borras, 2013).

4. Material and methods

Using the 'income capitalization' method, the real estate value of the set of agricultural plots belonging to a farm (*J*) is calculated using the following formula:

$$\sum_{j}^{J} PV_j = \frac{RIP_{1j}}{(1+r_2)^1} + \frac{RIP_{2j}}{(1+r_2)^2} + \ldots + \frac{RIP_{nj}}{(1+r_2)^n} \quad (1)$$

Where PV_j is the capitalization value of the parcel *j* (€/ha); RIP_1, $RIP_2 \ldots RIP_n$ is the real or potential annual income[4] from the parcel *j,* from the first year until the end of the unlimited duration of the useful life *n* (€/ha); r_2 is the capitalization rate obtained by multiplying the general capitalization rate r_1 by the correction coefficient for olive groves of 0.43, which is specified in Annex 1 of the Land Law Regulations.[5]

With this methodology, it is possible to calculate the value of each parcel and later, assuming that the objective is to calculate the value of a whole farm, add together the values of all the different parcels, on the basis of the profitability per hectare. The profitability figure used for reference purposes is taken from studies carried out by public bodies, from surveys on the price of land (MAPAMA, 2016) and from the Olive Grove Master Plan (CPJA, 2015). However, none of these studies considers the inefficiencies in production due to fragmentation and dispersion or the impact of farm size. For demonstration purposes, the impact of fragmentation and dispersion is highlighted in Figure 2, which shows three farms with the same surface area (1 ha) but different structures. The farm in Square A has no inefficiencies due to fragmentation and dispersion, while those in Squares B and C have excess costs due to these factors, which reduce their income and by extension their real estate value.

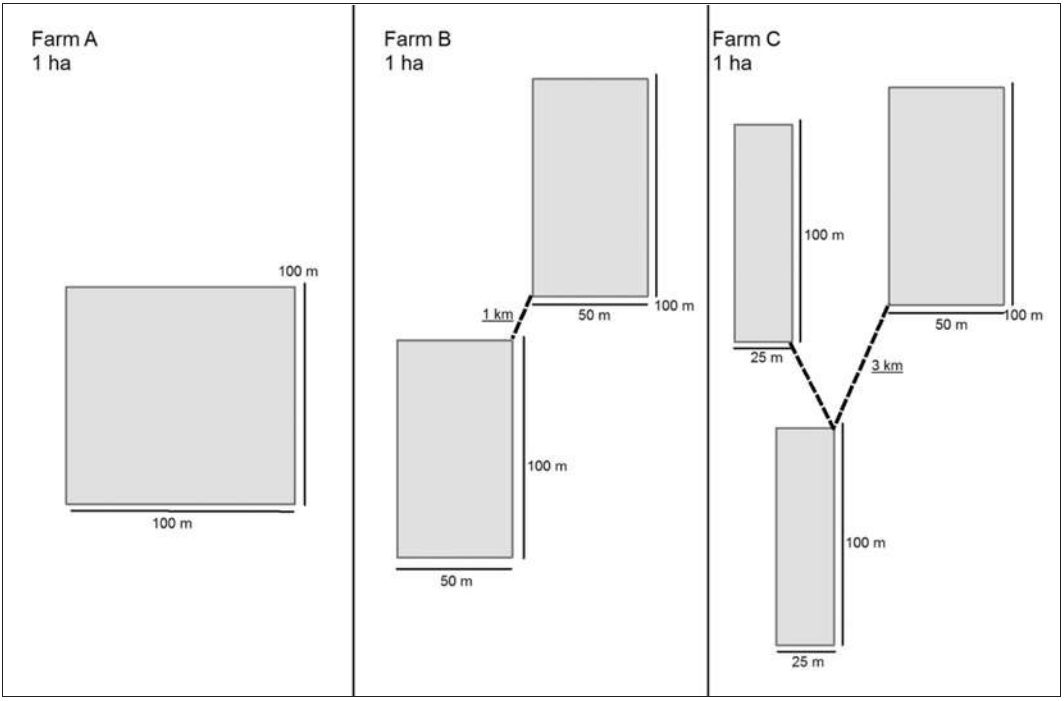
In this paper, in order to include the effect of structural factors on farm income we have considered the extra costs resulting from the fragmentation and dispersion of agricultural parcels, so as to subtract it from the total revenue entering the farm. The cost due to fragmentation, which is closely related to the number, shape and size of the parcels, has been calculated according to the methodology described in Colombo and Perujo-Villanueva (2017a). The cost due to dispersion has been estimated using the methodology proposed by Perujo-Villanueva and Colombo (2017).[6] The general production costs per farm size were obtained using a new software that allows the analyst to enter a wide range of specific data to provide an accurate picture of the production structure of the farm (Colombo *et al.*, 2018; Colombo and Ruz-Carmona, 2019). For these purposes we considered the most likely techniques, management methods and machinery used in the study area. The total production costs are 2547 €/ha, 2007 €/ha and 1513 €/ha for the 1 ha, 10 ha and 30 ha farms respectively.

[4] Real income will be understood as that resulting from the farming of rural land according to its state and activity at the time of valuation, be it the duly accredited existing income, or the attributable income according to the particular crops and other farming uses. Potential income will be understood as the income attributable to the farming of rural land in accordance with the most likely uses and activities that are feasible using the normal technical resources for its production.

[5] r1 is calculated according to Royal Decree Law 7/2015, which establishes: "1. For the capitalization of the real or potential annual income of a farm, as referred to in Section 1 of Art. 363, the capitalization rate to be used shall be the average value of the annual data published by the Bank of Spain about the profitability of Government Bonds at 30 years, which corresponds to the 3 years prior to the date to which the valuation is understood to refer." At the time of writing this paper the capitalization rate was 2.2%.

[6] Colombo and Perujo Villanueva (2017a) demonstrate that the number and shape of the parcels create inefficiencies in the various tasks involved in olive farming. This leads to an average increase in production costs of between 4.4% and 6.5%. These costs are higher in farms with small, elongated parcels. In addition, Perujo-Villanueva and Colombo (2017) estimated that the increase in production costs due to parcel dispersion, in other words, the time wasted by the farmer in covering the distance between his/her different parcels is between 1% and 10% and is more significant in small farms than in large ones.

Figure 2 - Different fragmentation structures in a typical 1 ha olive farm.



The procedure followed to estimate the production costs are described in papers by Colombo *et al.* (2016) for farms of between 1 and 10 ha and by Cubero and Penco (2012) for 30 ha farms. In both cases the data obtained refer to rainfed land. Revenues are calculated using average oil price values for the study area and subsidies over the last 10 years. Specifically, we assumed that the average price of olive oil was 2.51 €/kg.[7] We also assumed a production level of 3500 kg/ha and a greasy yield of 21%. The CAP subsidies were 500 €/ha. On the basis of these assumptions, the total revenues were 2,345 €/ha. The farmer's final income can be calculated by subtracting total production costs from the revenues.

The real estate value of the set of agricultural plots belonging to a farm can be calculated as follows:

$$FV = \frac{TRIF_1}{(1+r_2)^1} + \frac{TRIF_2}{(1+r_2)^2} + \ldots + \frac{TRIF_n}{(1+r_2)^n} = \sum_{i=1}^{n\to\infty} \frac{TRIF_i}{(1+r_2)^i} \quad (2)$$

$$TRIF_n = \sum_j^J RIP_{nj} - (IF_n + ID_n) \quad (3)$$

Where FV is the real estate value of the set of agricultural plots that make up a farm; TRIF, is the sum of the income from all the parcels in year n, including the costs resulting from fragmentation and dispersion. IF is the extra cost due to parcel fragmentation and ID is the extra cost due to parcel dispersion.

Clearly, the values for inefficiencies due to fragmentation and dispersion vary from one farm to the next due to their particular spatial structure and dimensions. In this paper the impact of fragmentation and dispersion on real estate value is calculated by applying the average levels of fragmentation and dispersion for all the traditional olive farms in Jaen with more than one parcel, according to the following size ranges: 0.1-1 ha, 1-5 ha, 5-10 ha, 10-50 ha and over 50 ha. These ranges were chosen because they are the most used in the bibliography for the olive sector. Lastly, given the likely impact

[7] This is the weighted average price of extra virgin olive oil, virgin olive oil and lampante oil.

of different capitalization rates on the real estate value of the parcels, we also carried out a sensitivity analysis using capitalization rates of 5% and 10%.

5. Results

The machine-workable traditional olive grove in the province of Jaen covers an area of 448,831 ha. This land is distributed amongst 84,788 farms or smallholdings. The largest olive farm measures 850 ha and the smallest just 0.04 ha. Table 1 shows the number of farms within each size range and the total area they occupy as a percentage of all the land occupied by olive groves. It is clear that the olive production structure is highly fragmented. In the province of Jaen, the size range with most members is 0.1-1 hectare (30.1%) and although 77.6% of the farms have less than 5 ha, these occupy just 27% of the total area of olive groves.

The costs resulting from the inefficiencies due to parcel fragmentation and dispersion are described in Table 2. The average inefficiency due to fragmentation for the province of Jaen is 14.7%, which results in an average cost of 100.8 €/ha, while the average effect of dispersion in production costs is 190.1 €/ha. The costs indicated in Table 2 refer to the average costs that the farms incur due to the fragmentation and

Table 1 - Farms by surface area.

Area (ha)	*Nº of farms*	*%*	*Aver. Area (ha)*	*Total Area (ha)*	*%*	*Aver. Nº Plots*
0.1 – 1	25484	30.1	0.5	15223.5	4%	1.4
1.01 – 2	18515	21.8	1.4	26906.1	7%	2.3
2.01 – 5	21821	25.7	3.2	65380.0	16%	3.5
5.01 – 10	9727	11.5	6.9	60631.4	15%	5.2
10.01 – 50	8074	9.5	19.5	136588.5	34%	7.4
>50	1167	1.4	95.0	94339.6	24%	11.1

Source: The authors - based on SIGPAC 2013.

Characterization of farms on the basis of their size/area and the average number of plots that make them up.

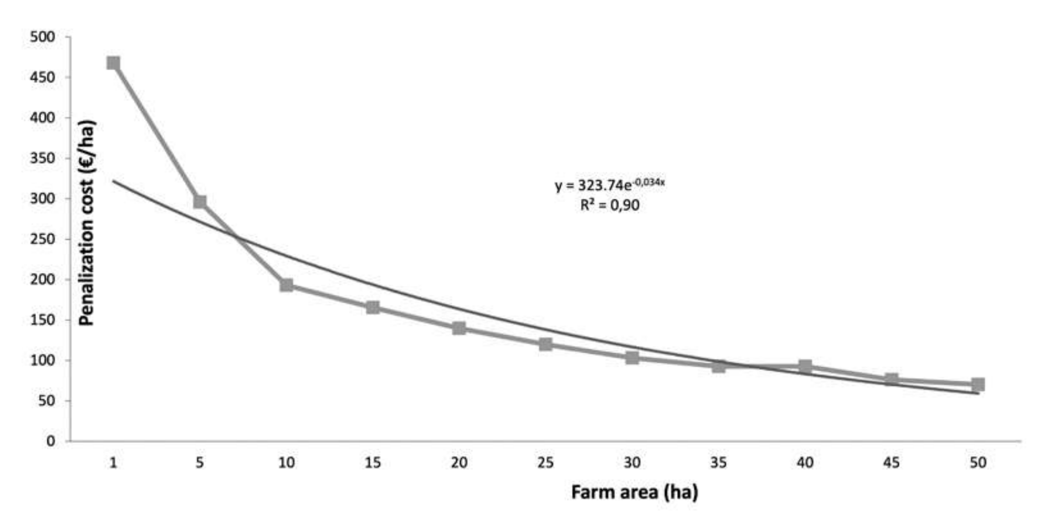
Table 2 - Average cost of parcel fragmentation and dispersion in the province of Jaén (Spain).

Area (ha)	*Inefficiency due to fragmentation (%)*	*Average Dispersion (km)*	*Cost due to fragmentation (€/ha)*	*Cost due to dispersion (€/ha)*	*Total cost (€/ha)*
0.1 – 1	20.1	2.6	137.1	225.1	362.2
1.01 – 2	16.8	4.0	114.9	227.9	342.8
2.01 – 5	14.8	6.0	101.3	163.2	264.5
5.01 – 10	12.6	8.5	86.5	106.6	193.0
10.01 – 50	9.6	10.8	66.1	70.3	136.4
>50	5.8	11.0	39.9	16.0	55.9

Source: The authors - based on SIGPAC 2013.

Determination of the penalization costs (fragmentation and geographic dispersion) according to the size of the farm.

Figure 3 - Correlation between the area of the farm and the penalization costs. Average values for the different size ranges.



dispersion of the plots. Clearly these costs vary according to the size of the farm, in that larger farms tend to have lower fragmentation and dispersion costs (Colombo and Perujo-Villanueva, 2017a; Perujo-Villanueva and Colombo, 2017). Thus, in order to calculate the real estate value of a farm using Formula 2, it is necessary first to determine the impact of fragmentation and dispersion as a function of farm size. This can be seen in Figure 3, which highlights the relation between farm size and the additional costs incurred due to fragmentation. As can be observed, the two variables have an exponential relationship, illustrating that the impact of fragmentation and dispersion on the profitability of small farms, and thus on their real estate value, is much greater than on medium-sized and large farms, which are much less affected. On average, on 5 ha farms the impact of fragmentation and dispersion causes a fall in income per hectare of 273 euros, whilst on a 30 ha farm this impact is much lower at 117 euros.

If we know the size of the farm, the equation shown in Figure 3 can be used to calculate the general reduction in its income due to fragmentation and dispersion. However, the impact can vary from one farm to the next according to the specific degree of fragmentation and dispersion, given that two farms with the same area can have very different spatial structures. The exact figure for these costs can be established using the methodology proposed by Colombo and Perujo-Villanueva (2017a) and Perujo-Villanueva and Colombo (2017). Detailed information (such as the shape and the geo-referenced location) about each of the parcels that make up the farm is also required. Unfortunately, this information is often unavailable and the calculation process can be too complicated for the valuer interested in determining the impact of fragmentation and dispersion on the income from the farm. A simpler way of assessing this impact would be to use the typical fragmentation and dispersion values for the different farm size ranges. In this paper, this was done by setting a threshold to establish whether fragmentation and dispersion were high or low within each size range. To do that, we used the median number of plots per farm in the case of fragmentation and the median distance between the plots in the case of dispersion for all the farms in the province. Logically, the more intervals we use, the more accurately we can calculate the reduction in the income due to fragmentation and dispersion. For instance, for the 0.1-2 ha size range, the median fragmentation value was 2 plots and the median dispersion was 2.8 km. That means a farm within this size with 2 plots and a dispersion of 4 km would be classified as having low fragmentation and high dispersion. When this procedure is extended to the whole farm, the valuer can obtain a more accurate estimate of the impact of fragmentation and dispersion on the income of each farm, simply by observing the number of plots and the average distance. The results are shown in Table 3. For farms in the 0.1-2 ha range, with low fragmentation and dispersion, the penalization costs would be 74.4 €/ha for fragmentation and 102.4 €/ha for dispersion. At the opposite end of the scale, in farms with high fragmentation and dispersion, the additional costs would be as high as 172.3 €/ha and 435.4 €/ha. In large farms however, these costs were less significant and more homogeneous. For example, for a slightly fragmented farm of over 50 ha, the combined cost of fragmentation and dispersion would be just 30 €/ha, while the same farm with high levels of fragmentation and dispersion would have penalization costs of 81.9 €/ha.

Table 4 shows the income from and the real estate value of the agricultural plots that make up a typical farm in the study area. The real estate value of the land belonging to a farm was

Table 3 - Penalization costs due to different levels of parcel fragmentation and dispersion by area range.

Area (ha)	*Low fragmentation (€/ha)*	*High fragmentation (€/ha)*	*Low Dispersion (€/ha)*	*High Dispersion (€/ha)*
< 2 (<=2 plots and 2.8km[a])	74.4	173.3	102.4	435.4
2.1 – 5 (<=3 plots and 4.1km[a])	67.5	135.7	71.6	258.6
5.1 – 10 (<=3 plots and 5.5km[a])	57.9	114.9	47.6	167.1
10.1 – 50 (<=4 plots and 5.1km[a])	42.3	90.7	26.9	114.6
>50 (<=5 plots and 2.0km[a])	26.2	53.7	3.8	28.2

Source: The authors - based on SIGPAC 2013.

a: Thresholds used to differentiate between low and high fragmentation and dispersion situations.

Penalization costs increase in line with the increase in fragmentation and dispersion. In this table we can see that these costs are higher on smaller farms.

Table 4 - Calculation of the real estate value of the farm according to its size.

Area (ha)	*Income without fragmentation and dispersion costs (€/ha)*	*Fragmentation costs (€/ha)*	*Dispersion costs (€/ha)*	*Total penalization costs (€/ha)*	*Annual income with penalization (€/ha)*	*Real estate valueA (rate 2.2%) (ha)*	*Real estate value (rate 5%) (ha)*	*Real estate value (rate 10%) (ha)*
1	-112	124	276	400	-512	-7333 (-33525)	-4700 (-21488)	-2677 (-12242)
10	338	79	94	173	165	22132 (10804)	14185 (6925)	8081 (3945)
30	832	56	42	98	734	54479 (48062)	34918 (30805)	19894 (17550)

Source: Present authors based on SIGPAC 2013.

A. The value in brackets includes the penalization due to fragmentation and dispersion costs.

This table shows the real estate values of farms according to their area and estimating the costs of fragmentation and dispersion.

estimated assuming constant income and the capitalization rate in force at the time the article was written (2.2%). The results of a sensitivity analysis using capitalization rates of 5% and 10% can also be seen. For 1 ha farms, the income was negative. In farms like these which are barely profitable, the income capitalization approach cannot be used for valuation, given that the real estate value of land cannot be less than zero in any expropriation or land consolidation process. The fact that small olive farms have negative incomes was confirmed by previous researchers (Colombo *et al.*, 2017) who found these farms are only viable thanks to unpaid work by family members. Secondly, for 10 ha farms, the value per hectare of 10,804 € was far below the market value, which according to the regional government was between 20,144 € and 33,871 € (CAPDS, 2018). If the same piece of land were valued without considering the fragmentation parameters, the real estate value would be 22,132 €, a value more in line with the current market value. The difference between the two valuations was very significant (51%), showing the large impact that fragmentation and dispersion can have on farm income. If we analyse the data for 30 ha farms, the real estate value of the agricultural plots that make up the farm would be 48,062 €, while according to the income capitalization' method, the value would be 54,479 €, a difference of 12%. Both values are considerably higher than the current market value, so revealing the severe impact that both size and fragmentation and dispersion costs have on farm incomes and thus on the resulting real estate value. The real estate value is also highly dependent on the capitalization rate used in the calculation. As shown in the last two columns of Table 4, if capitalization rates were higher at for example 5% or 10%, the real estate values would be 36% and 63% lower respectively than the value calculated using the currently applicable rate of 2.2%.

6. Discussion and conclusions

In Spain the valuation of farmland in public administrative procedures is conducted using the income capitalization method, which values the land according to its capacity to produce revenue. A realistic, accurate valuation is essential from a legal point of view as it has a wide variety of effects in a range of fields such as tax (tax payable), expropriations (for calculating the amount of compensation payable to the owner), mortgages (the land must be valued before a mortgage can be approved) and even for sentence enforcement purposes (judicial sales). The success of the valuation lies in obtaining a value as close as possible to the real market price. The current configuration of the 'income capitalization' method does not provide fair, accurate results especially when valuing farms with more than one plot. For example, a 6-hectare farm made up of 3 two-hectare plots and a dispersion of 15 km would have the same value as a 6-hectare farm made up of 2 three-hectare farms with just a track running between them.[8] The market operates in a different way setting higher prices for more concentrated, less fragmented farms.

For a fair valuation of farmland, it is therefore necessary to consider all the costs involved in the management of a farm without forgetting aspects which on certain occasions can create large differences in farm accounts and therefore in the income to be used as the base value. In this paper we have noted the impact that structural variables (such as the size, fragmentation and dispersion of the plots that make up the farm) can have on the real estate value of farmland, especially on small farms. The results show that economies of scale in production not only affect the profitability of the farm but also its real estate value. They also show that this effect is augmented by the fragmentation and dispersion of plots.

The valuation of farmland using the income capitalization approach is also affected by the capitalization rate. This means that the general financial situation, which is an exogenous factor

[8] The value could change if some of the parcels had different correction factors due to location. However, this seems unlikely with the values established in the valuation rules set out in the Land Act (Ley del Suelo RD 1492-2011).

of production, may have substantial effects on the price of land, reducing it significantly when the capitalization rate is high.

In order to maintain the real estate value of land it is essential to increase the size of farms and reduce fragmentation into smaller and smaller plots. Various solutions include the reorganization of farms, the concentration of plots and even the implementation of measures that enable farmers to purchase adjacent plots so as to reduce fragmentation. These changes in the land ownership system would make farms more productive, so increasing farming income and by extension the capitalization of agricultural land. Another option would be shared management of the land, either through shared or assisted cultivation (Colombo and Perujo-Villanueva, 2017b). These options increase the income from farming and thus the value of agricultural land. This means that public policies that encourage changes of this kind would also improve the welfare of rural areas.

The information generated during this research could be very useful for the public administration and for the owners of rural land in areas undergoing territorial reorganization processes, especially in places with very fragmented land ownership dominated by smallholdings. On the one hand, considering the role played by structural variables in the formation of income enables a fairer, more equitable valuation of the farmland in areas affected by processes of this kind. This could potentially increase the confidence of farmers in land consolidation procedures, making them more likely to participate (Kupidura *et al.*, 2014). Secondly the reduction in the real estate value of fragmented farms could encourage their owners to reach agreements to join their different plots together, so boosting the market for rural land, which tends to be very static.

The information produced in our research could also be very useful in the design of future laws for the reorganization of farms, such as for example the forthcoming Andalusia Agriculture and Livestock Act. The practical application of future laws must include penalization coefficients due to fragmentation and dispersion in different crops, which must be applied in land valuation processes in which at least two plots belonging to the same owner are involved. In situations in which the public administration is reorganizing the layout and ownership of farmland, the method for valuing the income produces a number of unknowns which must be resolved in the case of crops with a very low or zero rate of return such as traditional olive-farming. In the income capitalization approach, the formula used to calculate the real estate value of the land cannot be applied when the rate of return is zero or negative, and in these cases the real estate value of the land is normally calculated using a pre-established formula, capitalizing a theoretical income equivalent to one third of the minimum income of the land in that particular area.[9] However, it is important to bear in mind that these agrarian systems provide society with a whole series of non-commercial goods and services (Gómez-Limón and Arriaza Balmón, 2011), which if properly valued would significantly increase their income and by extension their real estate value. For example, from a social point of view, if the impact of self-employment were to be taken into account in the formation of income, we would obtain very different results in our income calculation (Colombo *et al.*, 2016). In this way crops with almost no real estate value from a professional perspective would have some value from a social perspective. Likewise, environmental considerations could be included in the estimation of income from traditional extensive farming after monetising the environmental externalities they originate (Colombo *et al.*, 2006; Villanueva *et al.*, 2014). Recent studies show that in the case of marginal farming systems such as traditional olive-growing, the production of environmental goods could be prioritised to the detriment of commercial products, making the "environmental income" the main income for these systems (Villanueva *et al.*, 2017). These aspects are an excellent basis for future research.

[9] Article 16 of the Valuation Regulations from the Land Act (Ley del Suelo RD 1492-2011).

Future research must also analyze the impact of the subsidy from the Common Agricultural Policy on the income used in the income capitalization method. These subsidies have a huge impact on the profitability of farms and on their real estate value. However, the uneven distribution of subsidies between farms causes large disparities in the valuation of the land regardless of their production capacity. Likewise, the gradual reduction of subsidies from the Common Agricultural Policy has led to a fall in rural wealth without a corresponding reduction in the production capacity.

This research has various limitations which must be considered when interpreting the results. Firstly, the complexity of applying the location factors proposed in the ATLLUR when valuing the land at farm level rather than at parcel level and given that different parcels may have different location factors. One possible solution could be to use the centroid of the farm as the point of reference (Latruffe and Piet, 2014) or to use the average distance from all the plots or from the plot with the largest area, establishing various standardization criteria (Marie, 2009). The impact of different farm location factors on the real estate value of these farms could be an interesting subject for future research.

Another limitation can be observed in concentration, reorganization or expropriation processes that affect some but not all of the plots belonging to the farm. In these cases, the object being valued must be the group of plots affected by the particular procedure and not the whole farm. Finally, we would like to make clear that the maintenance of rural heritage (food safety, environmental protection, supervision and care of rural territories, etc.) is key for the future of Europe. To this end public policies must plan tools that promote a system of agrarian ownership and management that increases the real estate value of farms and by extension the general welfare of rural areas.

Acknowledgments

This research was co-financed by the Andalusian Institute of Agricultural Economics and Training (IFAPA) project PP.AVA.AVA2019.031 and by the European Regional Development Fund (ERDF).

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Assessment of the economic sustainability of an organic olive oil farm in the Puglia Region (Italy) under the voluntary regional quality scheme

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DOI: 10.30682/nm2101h
JEL codes: D4, Q17

Abstract

The Puglia region is the most important producer of organic olives in Italy. The study aims at assessing the economic sustainability of a selected organic olive oil farm by adopting and testing the methodology based on a scientific approach designed by CIHEAM Bari, with the collaboration of a group of experts from national and international research organisations, used in the Programme "Agricoltura&Qualità" of the Puglia Region. A SWOT-analysis of quality schemes' system in Puglia has been drawn. The case study concerns a traditional organic farm producing olive oil, table olives, and almonds in the Puglia region. The SWOT analysis highlights that Puglia has not a fully functioning system to ensure sustainability. However, the results prove the feasibility of the methodological approach to assess the economic sustainability of the farm. Therefore, the farm is economically sustainable and can use the "Economic sustainability" logo, in addition to the organic and PDO logos. Per hectare, almond is the most profitable crop with the highest revenue, variable costs are higher in table olives and inputs are higher in olives for oil. The growing interest in sustainability is an important opportunity to develop the agri-food sector.

Keywords: *Sustainability guidelines, Organic farming, Olive oil farm, Economic indicators, SWOT analysis.*

1. Introduction

Nowadays, the sustainability concept is attracting increasing attention due to population growth and the depletion of natural resources. There are different definitions of sustainable development, but the most widely accepted one is from the report "Our common future" released in 1987 by the World Commission on Environment and Development (WCED) chaired by Gro Harlem Brundtland, stated as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs". Based on this definition, sustainable development refers to three major components: social equity, economic viability and environmental sustainability. Economic sustainability is defined as the ability to generate a durable growth of economic indicators, notably the ability to generate income and employment for the population's livelihood (Spangenberg, 2005).

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Different approaches have been developed with respect to issues of sustainability, including organic farming (Eyhorn *et al*., 2019). It is continuously emphasising the relationship between the multifunctional role of agriculture (Saker *et al.*, 2018), as well as organic farming, and the concept of sustainability for several reasons. Firstly, organic farming is considered a production method with no negative impact on human health and the environment, while providing a sustainable income to farmers (Reganold and Wachter, 2016; Ramankutty *et al*., 2018). Furthermore, organic farming may be considered as an optional approach towards sustainability that can sustain agricultural production in the long-term, but it should be adapted to the local conditions and local crops (Šūmane *et al*., 2018). Local crops provide sustainable production and they are economically feasible for the community (Shelef *et al*., 2018). Besides their importance as local cultivations (Saponari *et al.*, 2018), olive crops represent one of the most important sources of income and employment for the Italian rural economy (Stillitano *et al*., 2016), mainly in the southern regions, and they are also one of the key players in supporting rural economies in the Mediterranean region (Iofrida *et al*., 2020). Organic olive crops in Puglia, in south-eastern Italy, represent 30% of the total surface allocated to organic olive growing in Italy (SINAB, 2018) Furthermore, it is one of the leading regions in the Italian organic sector in terms of cultivated surface and number of operators, with many hectares of organic crops such as olive, almond, grapes, etc. (SINAB, 2018; Biobank Open Project, 2018). Hence, the organic surface of the Puglia region represents 14% of the Italian organic surface. The portion of organic agricultural land allocated to organic olives growing represents 27% of the total olive-growing surface of the Puglia region. The area around Bari, a province of the Puglia region, is the largest producer of olive oil by volume in Italy. In the Bari province the organic surface represents 14% of Puglia's organic surface. The portion of organic land dedicated to organic olives in the province of Bari represents 24% of the total organic olive-growing area. Bari represents 32% of the total organic olive-growing surface area in Puglia (SINAB and Biobank Open Project, 2018).

Actually, more and more attention is being paid to the sustainability of typical agro-food products (Malorgio *et al*., 2015, Capone *et al*., 2016). However, while producers give particular importance to economic sustainability, greater weight is given by consumers to the environmental one. As for economic sustainability, it is mainly related to profitability for producers, while consumers associate it with accessible prices. This creates a trade-off between consumers and producers and policy should mediate between the two in order to find a balance between these different sustainability understandings and aspirations of two important actors of the agro-food chain. This is a concrete challenge also for the government of the Puglia region.

The Puglia Region (Regional Government of Puglia) has increasingly focused on measurement tools to assess the sustainability of agri-food production so as to support both private and public decision making, as well as to meet the demand of consumers for high quality and low impact products.

In the framework of the Programme "Agricoltura & Qualità" of the Puglia Region, the CIHEAM Bari carried out a pilot project with the objective of assessing and promoting the quality and the sustainability of traditional and typical food products through a scientific methodological approach under the voluntary Regional Quality Scheme "Prodotti di Qualità Puglia", in accordance with the Regulation (EU) No 1305/2013. The Regional Quality Scheme (RQS) is a certification that promotes regional quality products, related to plant and animal food products (including fish products) and floriculture. Through specific Production Standards (specifying the characteristics of products and their production process), approved by the Puglia Region, food safety, appropriate agronomic techniques, plant health, animal welfare and environmental protection are ensured (Regione Puglia, 2016). The International Centre for Advanced Mediterranean Agronomic Studies of Bari (CIHEAM Bari), with the scientific and technical collaboration of sustainability experts from several Italian scientific institutions, namely the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), the Research Centre on Food and Nutrition (CRA-NUT), the National Research Council (CNR), University of Bologna Alma Mater Studiorum, University of Naples Federico II and the Forum on Mediterranean Food Cultures, set up the optional "sustainability" prerequisite guidelines to assess and promote the sustainability of agri-food products through a scientific methodological approach applying the "additional sustainability logo".

This framework relates to the production system such as farm size, capital, farming activities, agricultural practices and the adoption of technological innovations. Particularly, the voluntary sustainability standard can create added value for small farmers.

The optional "sustainability" prerequisite guidelines, and particularly, the economic sustainability indicators (Capone *et al.*, 2016), were developed in 2015-2016 as a theoretical methodology. Nonetheless, it needed to be implemented in a case study and tested on real data. In this paper, however, it is the first time that the sustainability methodology is implemented using real data from organic farms in the Puglia region in Italy.

The purpose of the present study is to apply a preliminary methodological approach and economic indicators in order to assess the economic sustainability of organic olive oil farming in Puglia. Moreover, a SWOT analysis was performed on the system of quality scheme.

The main objectives of this study are:

1. To analyse the organic olive oil sector in Puglia.
2. To carry out an economic analysis of a pre-selected "traditional organic olive oil farm".
3. To implement and verify the feasibility of the methodological approach under the regional quality scheme "Prodotti di Qualità Puglia" and to assess the economic sustainability of the case study in its territorial context.
4. To evaluate whether the "additional sustainability logo", certified by the Puglia Region, can be attributed to the selected organic olive oil farm.
5. To apply a SWOT-analysis of regional system of quality schemes (Protected Designation of Origin, Protected Geographical Indication, Organic certification and "Prodotti di Qualità Puglia" promoted by the European Union).

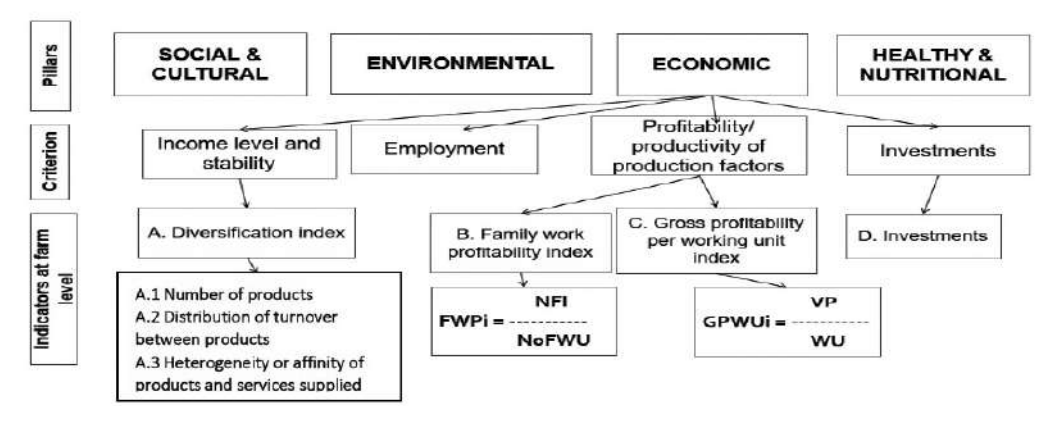
This paper mainly considers the traditional organic olive farm as a case study for the assessment of economic sustainability. This farm is not representative of all farms in general; as a matter of fact, the criteria of selection have been drawn in accordance with the main characteristics of the current and traditional example of olive farming in rural areas in Puglia.

2. Materials and methods

To apply the principles of sustainability and to assess the economic sustainability of the selected organic olive oil farm the scientific methodological approach developed in the "Agricoltura & Qualità" program of the Regione Puglia was adopted. The methodological approach used is in line with the Sustainability Assessment of Food and Agriculture Systems (SAFA) approach, based on the adoption of a hierarchical approach (FAO, 2013) from sustainability themes to indicators for each dimension (Figure 1). The methodology aims to evaluate the sustainability separately for the four dimensions (environmental, economic, socio-cultural and nutritional-health) and each of these dimensions has the same importance as the others. For each sustainability pillar, some criteria were identified and for each criterion some indicators were selected. For this study, an assessment of economic sustainability has been carried out. Thus, specific criteria and indicators were selected to measure the economic sustainability performance in a reliable way at farm level and to determine progress towards sustainability.

The identified criteria of economic sustainability refer to income level and stability, investments, employment, profitability and productivity of production factors. Furthermore, for each criterion some indicators were selected that were suitable and measurable at farm level (Capone

Figure 1 - The methodological approach from sustainability themes to indicators for each economic dimension.



et al., 2016). The economic sustainability indicators used to assess the economic sustainability of organic olive oil farming are described in the Programme in "Agricoltura & Qualità" of the Puglia Region (Figure 1). The assessment framework can be applied in a different context to evaluate management systems and decision-making and to distinguish potential areas of policy interventions. Each selected economic sustainability indicators was calculated according to the calculation method described in the methodology. Then, selected indicators with different units were normalized in relative terms with the appropriate coefficient determined in the programme to have values in the same unit and to make them easier to aggregate.

According to the number of products and services made by the company (A1), when no product is produced, the score is equal to 0 points, if there are 2 products it represents the benchmark and the score amounts to 0.5 points; if there are 4 or more agricultural products the score is = 1. The score is multiplied by a weighting factor of 0.5. For the distribution of turnover between the different products and services (A2), values from 0 to 1 are assigned based on the percentage weight of the production value of the first product or extra- agricultural activity. If the first product or non-agricultural activity holds 100% of the value of the total production of the company, a score equal to 0 is assigned. If the first product or business holds a value greater than or equal to 70% of the value of the company's production a score of 0.3 is assigned; 0.5 points are given if the first product or activity reaches 50% of the value of the company's production; 0.7 points are assigned if it reaches 40% of the production value; 1 point if the first product or activity reaches 30% of the value of the company's production. The score obtained should be multiplied by a weighting coefficient of 0.2. In case of the heterogeneity or proximity of the products and services offered (A3): if the company only manages the agricultural activity the score is equal to 0.3 points; if, besides the agricultural one, it carries out another activity, whether it be of transformation or within the framework of multifunctionality, the score is 0.6 points, if in addition to the agricultural one it carries out two activities one point is awarded. The score obtained should be multiplied by a weighting coefficient of 0.3. The values (derived from the sum of the multiplication of the weighted scores of the three elements) that the DI can take varies from a minimum of 0 (in single-product companies) to a maximum of one. The value of 0.5 is the reference average. In particular, the degree of diversification is accentuated when production increases, with a "balanced distribution of turnover among the various products, and to increase the heterogeneity between the products. This last feature is evidently increased by the introduction of the supply of both food and non-food products and services in the company (broadening and deepening).

During this step, scales of measures were converted into a comparable scale. The normalized indicators should be aggregated to obtain the final value which can summarize the information related to the economic dimension. The sustainability benchmark value was defined for each indicator. The sustainability benchmark represents in a numerical form the threshold of sustainability beyond which a product, and/or the company that produces it, can be considered sustainable. This value was defined by CIHEAM Bari with the support of experts from several research institutions, taking into account the average performance of Puglia agri-food companies or national and European Union standards/regulations. Based on the principle of continuous improvement, the sustainability benchmark values will be updated every 5 years. Once the benchmark had been determined, a scoring system was developed for each indicator referring to each product and supply chain; from 0 (unsustainable) to 1 (very sustainable), the benchmark corresponds to the score 0.5.

The farm, submitted to the Regional Quality Scheme (PdQP) with a sustainability benchmark value at least 0.5, can demonstrate its submission to the optional "sustainability" prerequisite using the "additional sustainability logo" (Figure 2) written on the product/s complying with guidelines of the Puglia Region (Regulation (EU) No 1305/2013). The enterprise can demonstrate its subscription to the optional "sustainability" prerequisite by applying the "additional sustainability logo" on product/s. The logo is made up of three sustainability dimensions completed with the health-nutritional component. The "additional sustainability logo" guarantees the sustainability of the farm process carried out to grow or produce the product from an environmental, economic, socio-cultural and nutritional health point of view. The procedures for permission to use the "additional sustainability logo" are defined in the guidelines. It can be considered as an innovation protecting the quality of local food products via an interdisciplinary approach taking into consideration environmental issues and various aspects pertaining to food, habits, customs and traditions, health and the community's economic benefits (Capone *et al*., 2016). The methodological approach can be applied to who demand, as approved by Regione Puglia, the use of the additional "additional sustainability logo" for the products that adhere to the regional quality scheme or to other quality schemes recognized at EU level. It is applicable to a single farm as well as groups of farms joining the Quality Scheme and organized in chains. Hence, the application for the use of the "additional sustainability logo" has to concern four pillars: environment, economy, society-culture and nutrition health (Figure 2).

Figure 2 - Additional sustainability mark (logo).

The Puglia Region assesses the proposal of the farm in relation to the criteria identified in the sustainability guidelines and grants the transitional use of the "additional sustainability logo". Particularly, the logo may be used on the products subjected to the RQS and to the sustainability criteria defined by the sustainability guidelines. In case of partial approach of sustainability, i.e. the product does not comply with all 4 pillars, the "additional sustainability logo" will display only the dimension/s applied, for a transitional phase (one year). However, at the end of the transitional phase, sustainability of the farm will be evaluated for each one of the sustainability pillars (environment, economy, society-culture and nutrition-health) that have equal importance as a subsequent normal phase (Malorgio *et al*., 2015). After the transitional phase, on the basis of the gained experience, the Puglia Region will define a sustainability standard with the related indicators to be fulfilled by the businesses that intend to use the "additional sustainability logo" under normal operating conditions (Regione Puglia, 2016).

Step 1: Identification of criteria and selection of the farm

The farm was selected based on the following criteria: location in the Puglia region (province of Bari); organic farm (whole organic surface); more surface of olive trees (> 10 ha) in whole farm; the farmer should be an olive specialist according to the classification of agricultural holdings by type of farming (> 50% of total standard output); parameters to define traditional farming (layout 5 x 6 m or 6 x 6 m or 7 x 7 m; 15-50 years old; local varieties: Coratina, Cima di Bitonto, Termite di Bitetto); diversity of crops (besides olive trees: almonds); professional farmer (entrepreneur); irrigation system; olive processing for third parties and sale of extra virgin olive oil by the farm itself; certification of quality systems; farmer's activities third party.

The case study was carried out in an organic traditional farm in Modugno, in the province of Bari, located in southern Italy. The site is characterized by a typical Mediterranean climate and it consisted of traditional organic farming with irrigation system. In the selected farm, olives for oil, table olives and almonds were grown. The land area was distributed as follows: 14.55 ha for olives trees for oil, 1.4 ha for olives tree for table olives and 2.2 ha for almond trees. The main varieties used for olive for oil are Coratina and Cima di Bitonto, Termite di Bitetto for table olives, while the variety used for almonds is Filippo Ceo. These local varieties had layout 6 x 6 m and are 25-30 years old. The farm is specialized in the cultivation of olives since 69% of its gross value is linked to olives. A microeconomic analysis of a local farm was performed, where processing was done by third parties. In order to favour an economically sustainable olive production, the selected farm aimed to improve profitability through investments in quality schemes. The farm was certified for the following standards: Organic certification, Protected Designation of Origin (PDO) and traceability procedure.

Step 2: Drafting the questionnaire for the selected farm and data collection

The economic data were collected through a questionnaire on organic olive oil and almond conducted in November 2018 that allowed to gather detailed information on: farm structure (type of orchards); inventory of machines, buildings, improvements and land labour (considered entirely as seasonal labour as well as the opportunity costs); variable costs and outputs by olive orchards type and almonds; other information (consultancy, insurance, participation to expos, certifications); information on market channels. The collected data referred to the two accounting periods (2 years) since hard pruning is commonly carried out every two years for olive trees which highly influences the alternate bearing. Missing or incomplete data were collected through official websites or interviews to local experts. The data related to the agricultural machinery efficiency and to the characteristics of olive plantations were compared with the Italian references to improve their accuracy. The collected data were used for evaluating each indicator.

Step 3: Enterprise budget and economic indicators

After the data collection, a Microsoft Office Excel sheet was designed to support the accounting functions such as crop budgeting for data compiling and elaboration. The main budgeting report was an enterprise budget considering three organic crops (olives for oil, table olives and almonds), where data was calculated using economic indicators such as gross margin (GM) and net farm income (NFI), in order to assess the economic sustainability of the farm. Variable costs included: inputs (e.g. pesticides, fertilizers, pruning, irrigation, fuel, harvesting, processing), seasonal labour and interest on previous costs. Fixed costs included: certification, permanent labour and depreciation cost. The economic sustainability indicators at farm level were: diversification index (DI) with its three components, investments or procedures adopted by farm, family work profitability index, and gross profitability per labour unit index.

SWOT-analysis of the quality schemes' system in the Puglia region

The analysis of quality schemes in the Puglia region was performed with the help of the SWOT methodology, an effective strategic development tool that was used to evaluate strengths, weaknesses, opportunities, and threats of the quality schemes' system in Puglia. The main strengths, weaknesses, opportunities, and threats were identified and described. The strengths and weaknesses are considered internal to the system/sector and represent the present situation, while the opportunities and threats are external (e.g. represented by the environment external to the sector) and represent a possible future.

Table 1 presents a SWOT analysis regarding the implementation of quality schemes in the Puglia region. The SWOT framework was carried out through a collection of data from bibliographic information related to implementation of quality schemes in the Puglia region, by identifying external factors (i.e. opportunities and threats) and internal factors (i.e. strengths and weaknesses) (Lurati and Zamparini, 2018).

SWOT-analysis highlighted that Puglia has not a functioning system to ensure the sustainability. One of the main strengths identified by the study was that a theoretical methodology for sustainability exists. The data needed from the Puglia region and other sources are indeed available. This availability made easier to estimate economic sustainability indicators at farm level. Specifically, the analysis highlighted the weakness that no references exist about the sustainability methodology of the Programme "Agricoltura & Qualità" which it is not implemented

Table 1 - SWOT analysis for regional quality schemes in the Puglia region.

Strengths	*Weaknesses*
• High quality, safe and traceable products	• High certification cost
• Availability of data (sources, references, data bank)	• Lack of a functioning system to ensure the sustainability
• Warranties for consumers / high requirement for local production (region provides products with high quality)	• Prodotti di Qualità Puglia (PdQP) has lower diffusion
• High weight of BIO certification in the Puglia region/large organic surface (importance of organic farming)	• Application of sustainability requires external ways
• High number of PDOs and GPIs in Puglia	• Lack of consumers' awareness
Opportunities	*Threats*
• Increasing interest by consumers in certified products	• Economic crisis/Instability of markets
• Increasing demand for traditional and typical products, fostering export	• Frauds/Imitation
• Regional Government support to rural development and regional quality schemes	• Limited level of education of stakeholders and consumers
	• Lack of policy coordination in support of methodology

Source: Own elaboration from our work during the year and literature review: Trienekens and Zuurbier, 2008; Barjolle et al., 2010; Janssen and Hamm, 2012; Scuderi and Pecorino, 2015; Comino and Ferretti, 2016; Palmisano et al., 2016; Perito et al., 2019.

at this moment. Also, the awareness of sustainability, particularly for consumers and policy-makers, is still limited.

3. Results and discussion

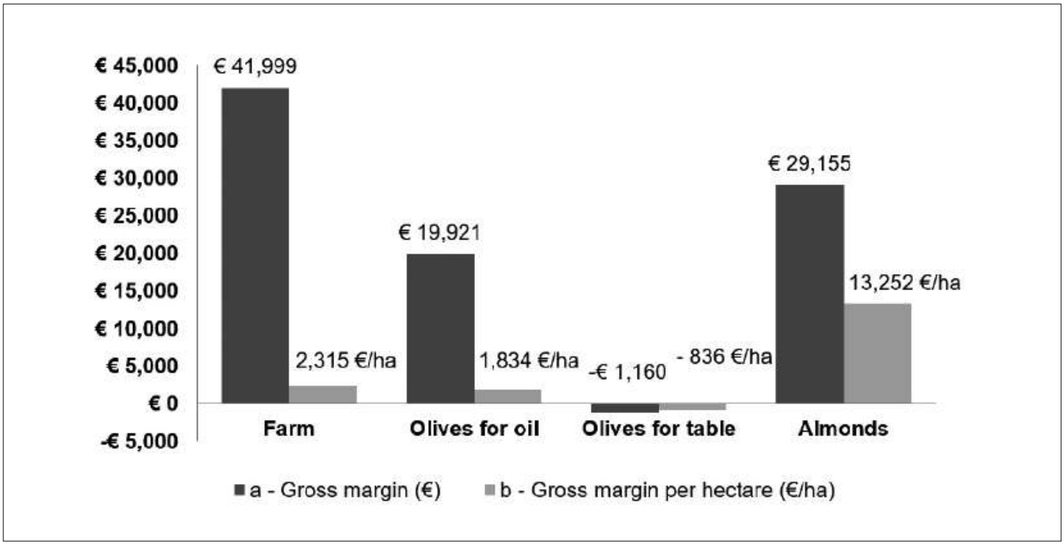
Results are presented and commented in two main parts. The first part focused on the gross margin and net farm income or three crop budgets and the enterprise budget, underlining profitability and performance of the farm. The results referred to two years of production and they were expressed in euro per hectare (€/ha). In the second part the selected economic indicators by the optional "sustainability" prerequisite guidelines were estimated, normalized and aggregated into composite indices. The final result determines that the selected farm is sustainable from the economic point of view or not. The indicator value concludes the probability to the use the logo "economic sustainability" by the selected organic olive oil farm, certified by Region Puglia.

3.1. *Economic dimension of case study*

The *total farm gross margin,* that is, the farm profit made after paying off its cost of goods sold, was approximately 42,000 €, while gross margin of farm per hectare was 2,315 €.

Per hectare, gross margin value tended to be the highest in organic almonds and the lowest in organic olives for table. Figure 3b shows that almonds were the most profitable crops with 13,252 €/ha, while the less profitable (losses) were table olives crops with 836 €/ha (Figure 3b). Almond crops generated higher income than the other crops, followed by olives for oil, the second most profitable crop in the farm. The third crop, table olives, showed a negative gross margin. This result was mainly due to the high human labour and pruning cost, as a result of its high density and canopy, confirming the insights of Mohamad *et al*. (2013). Since the quality of the olive's fruit has a crucial role in its marketing, the crops allocated to table olives was harvested manually. The study carried out by Famiani *et al*. (2014) confirmed that oil extracted from the mechanically harvested olives is of high quality and that the lowest harvesting cost for oil production is achieved thanks to harvesting machines. Anyway, the organic table olives orchard has lower yields than the orchard of olives for oil, particularly since the risk of losing olives because of insects is high. Moreover, the need for heavy annual pruning, manual har-

Figure 3 - The total gross margin of the farm and all organic crops cultivated in the farm expressed in euro for total surface (a) and comparison of the total gross margin between all organic crops cultivated in the farm expressed in €/ha (b).



vesting and large amounts of water for irrigation involve high costs for inputs and labours, and although the unit price is slightly higher than the olive oil unit price, revenues are lower. Therefore, the profitability of table olives production is a delicate issue due to low prices and steadily rising production costs (Jimenez-Jimenez F. *et al.*, 2015). In other words, low and sometimes negative profits, particularly in the years hit by more damages caused by insects and adverse climatic conditions, are not viable for the farm.

Average gross margin data of Rural Development Programme (RDP) Puglia 2014-2020 showed that gross margin per hectare of organic olive farm was 773 € which is lower the estimate produced by this study. As the gross margin is the difference between the total revenue and the total variable cost, it was needed to perform analyses of revenue and variable costs.

The *total farm revenue* was 113,897 €, but the revenue of the farm per hectare was 6,278 €. In the case of comparison of total revenue for each crop of the farm's total surface, the highest revenue was generated by olive oil with 21,838 € (14.55 hectares) (Figure 4). The crops of olives for oil generated 63% of total revenue.

Per hectare, the differences in revenue between the crops showed that the highest revenue was generated by almond (without hull) with 15,900 €/ha (2.20 hectare) compared to other crops as it is demonstrate in Figure 4b. Although the almond crop has a lower yield, its higher price explains why this crop reaches higher revenues per hectare (18 €/kg). Figure 4b shows that table olives had higher revenue than olives for oil. Previously, the data showed that table olives showed a negative gross margin. RDP 2014-2020 shows that the average revenue per hectare of the organic olive farm was 1,099 €. After comparing with RDP, it can be concluded that the selected farm generated a higher revenue. As almonds generates a lot of revenue, the farmer may increase emphasis on this agri-food product. At the same time, the farmer may reduce emphasis on crops that did not generate high revenues.

Table 2 shows yield and subsidies for each crop cultivated in the farm. For the reasons mentioned above for table olives, the gross margin per hectare is negative. Consequently, yield in euro per hectare will be low. Several studies defined independence from external inputs as an indicator of economic sustainability. Farm dependency on external finance should be optimal to because it may hamper innovations (Spicka *et al.,* 2019). RDP Puglia 2014-2020 showed

Figure 4 - The total revenue of the farm and all organic crops cultivated in the farm expressed in euro for total surface (a). Comparison of the total revenue between all organic crops expressed in €/ha (b).

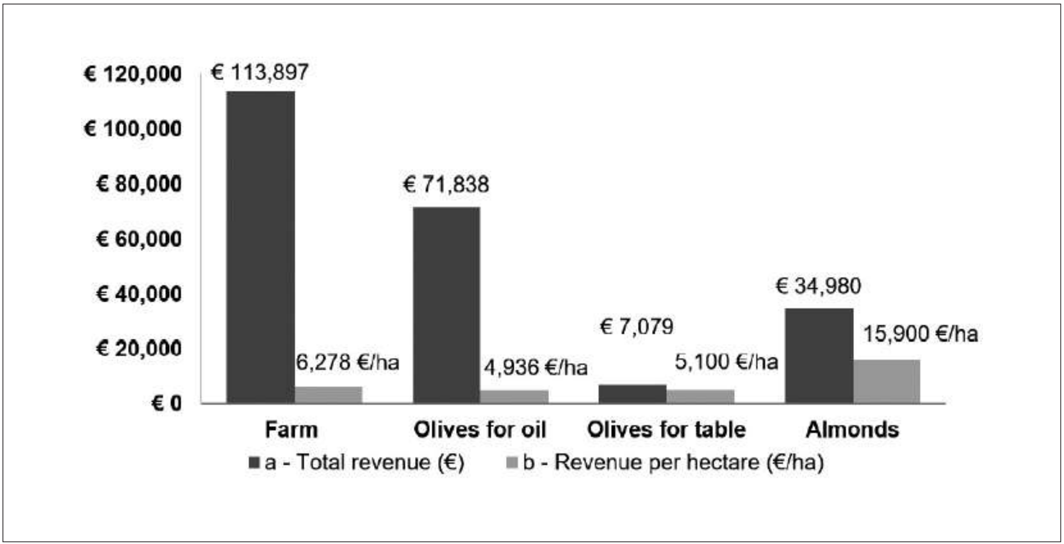


Table 2 - Yield, price and subsidies values of all crops.

Crops	*Olive oil*	*Table olives*	*Almonds*
Yield (ton/ha)	7.43	4.86	5.50
Yield (€/ha)	57,183	5,830	33,000
Subsidies (€/ha)	1,007	900	900

that average yield per hectare in an organic olive farm was 3.3 €. The selected farm has generated a high yield. In Puglia, the available data on almonds are amalgamated in the range of stone fruits, which makes it obscured.

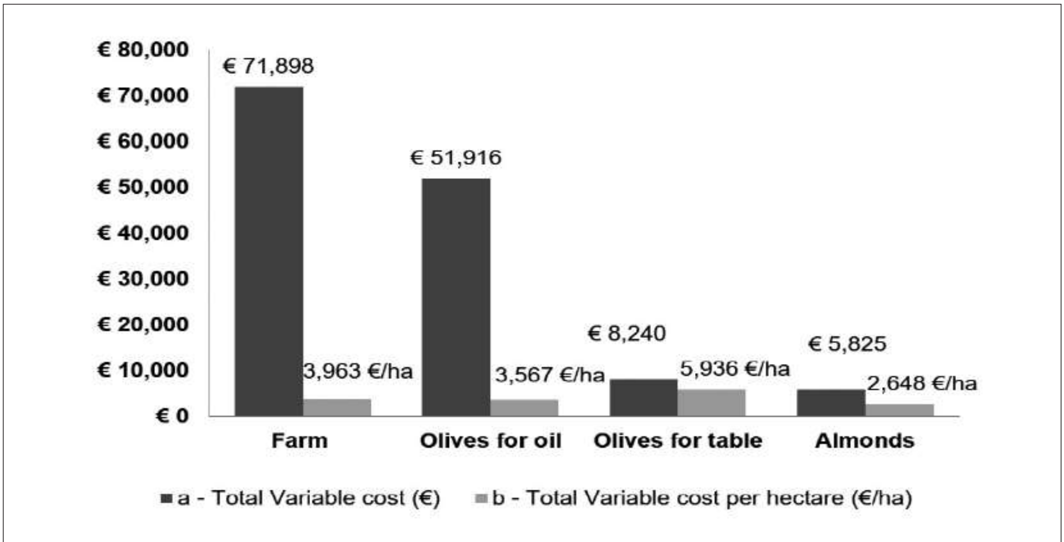
The *total farm variable cost* was 71,898 € and variable cost of farm per hectare was 3,963 € (Figure 5a). RDP 2014-2020 showed that the average variable cost per hectare of organic olive farm was 325 €. Organic almond was the crop with the lowest production cost (Figure 11b). The total variable cost of organic almonds was mainly influenced by the lower fertilization, labour, pest management, pruning and fuel costs.

The *total farm input cost* was 29,377 € and, per hectare, farm input cost was 1,619 € (Figure 6a). Based on input cost, the almond crop followed a similar rule as the total variable cost (Figure 6b). The almond crop had the lowest input cost while table olives crop had the highest input cost. According to the analysis, almond crop showed lower requirements for fertilization and pest management.

Inputs needed for the crop allocated to table olives were higher than the other crops except soil operation and processing (not applicable).

The pruning and harvesting costs had the highest impact on the total input cost. On the contrary, the other agricultural activities had a lower influence on the total input cost. The higher input cost of pruning was was linked to the crop of table olives due to the higher number of trees per hectare as well as its morphological characteristics. These data are in accordance with a study carried out by Mohamad *et al.* (2013) which highlighted that the olive pruning cost was higher due to its high density and canopy. The almond crop had the lowest input cost of pruning. The harvesting cost was lower in crop of olives for oil due to less hours dedicated to labour and a lower use of shakers. On the contrary, the harvesting cost was higher in the crop for table olives due to higher working hours. The crop allocated to table olives was traditionally

Figure 5 - Total variable cost of the farm and all organic crops cultivated in the farm expressed in euro for total surface (a). Comparison of the total variable cost between all organic crops expressed in €/ha (b).



harvested manually since the quality of olive's fruit has an essential role in its marketing. The study carried out by Famiani *et al*. (2014) concluded that oil obtained from the mechanically harvested olives is always of high quality. Also, it confirmed that the lowest harvesting cost for oil was obtained with the harvesting machine. Processing cost was applicable for crops for olive for oil and almonds.

The *total labour cost* was 40,767 € and labour cost per hectare was 2,247 € (Figure 7a). Labour cost per hectare turned out to be the highest in the crop for table olives and the lowest in almond crop (Figure 7b). This is a result of the pruning and harvesting cost. During harvesting of the crop for table olives, to avoid damage of olive fruit that can reduce fruit quality both, it required more hours of

Figure 6. Total input cost of the farm and all organic crops cultivated in the farm expressed in euro for total surface (a). Comparison of the total input cost between all organic crops expressed in €/ha (b).

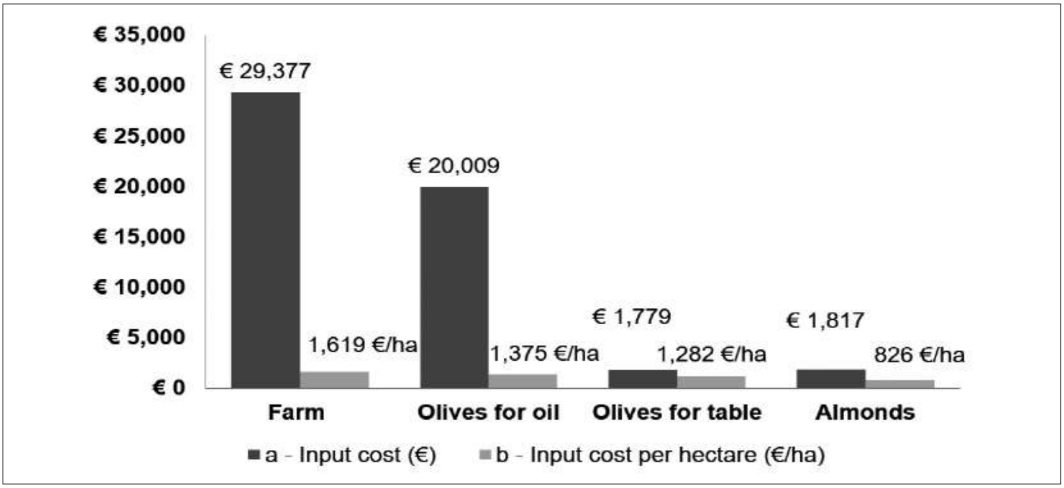
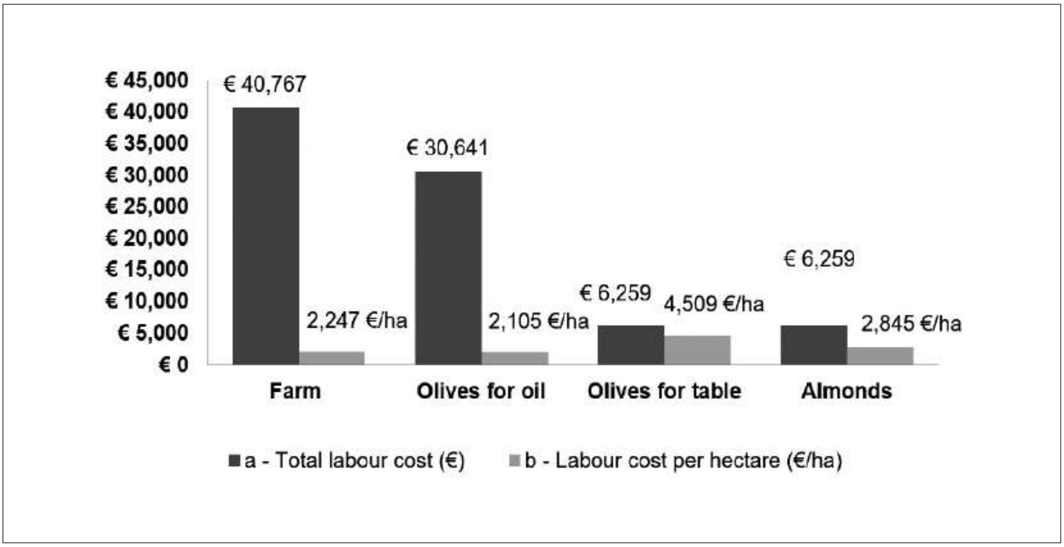


Figure 7 - Total labour cost of the farm and all organic crops cultivated in the farm expressed in euro for total surface (a). Comparison of the total labour cost between all organic crops expressed in €/ha (b).



labour. Another explanation was the high density of table olives per hectare.

The production costs for the crop allocated to olives for oil production was 3,866.4 €/ha, whereas the costs for the crop of table olives was 6,382.9 €/ha and 2,842 €/ha for the almond crop. Higher revenues and lower production costs were the reasons why the almond crop was more profitable.

The ratio gross margin on yield indicated that to produce one ton of olives for oil, the farmer earned 184 €/ha. Moreover, to produce one ton of almond crop the farmer earned 2,409 €/ha. This ratio confirmed once again that the almond crop was the most profitable one, contrary to the crop for table olives, which had the lowest revenues. *Labour on variable cost ratio* showed that for each 1 € paid as a variable cost the farmer paid 0.57 € as labour cost. Comparison between the crops showed that the crop for olives for oil had the lowest labour on variable cost ratio. For 1 euro paid as a variable cost, 0.55 € was paid as a labour cost for the crop for table olives, showing that the portion of labour cost was the highest for the crop for table olives. This crop needed more labour for its growing operations since the density of trees for hectare was higher. *Input on variable cost ratio* pointed out that for each 1 € paid as a variable cost the farmer paid 0.41 € as input. Results showed that the value of this ratio was higher in the crop for table olives, meaning that the portion of input cost in the crop for table olives was higher which required a more costly input. Thus, for 1 € paid as variable cost, 0.16 € was paid as input cost in case of table olives. Similarly as for labour on variable costs ratio, the crop for table olives had a lower portion of inputs. *Revenue on variable cost ratio* indicated that for each 1€ paid as a variable cost the farmer earned 1.58 € as revenue. For the almond crop, which was the most profitable crop in the farm, for 1 € paid as variable cost the farmer earned 2.73 € as revenue. Once again, increased selling price proved that almond can be highly profitable, especially with lower cost as resulted in this study. *Revenue on labour cost ratio* showed that for each 1 € paid as a labour cost the farmer earned 2.79 € as revenue. This ratio indicated that for each 1 € paid as labour cost, the farmer earned 2.54 € as revenue for the almond crop. This shows that the almond crop had the highest labour efficiency.

3.2. *Economic sustainability assessment and benchmark values*

The results for the sustainability indicators are presented below.

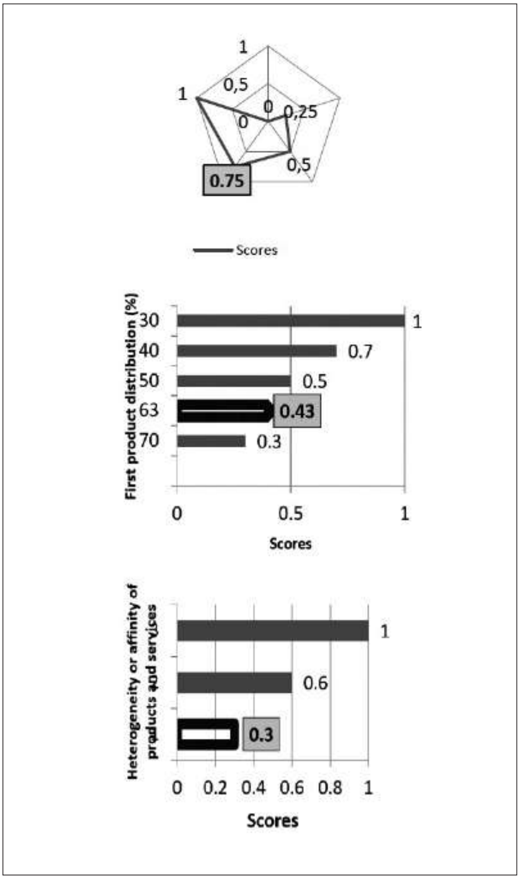
3.2.1. *Diversification index*

Since three products were grown in the farm (olive oil, table olives and almonds) the score of this component was equal to 0.75 points (Figure 8). After multiplying this value by the coefficient 0.5, the value of current component turned out to be equal to 0.375.

The crop of olives for oil accounted for 63% of the farm's production value. It is in accordance with the Commission Regulation (EC) No 1242/2008 that a farm is considered specialized in olives when its olive production represents more than 50% of the total production. A score of 0.43 (Figure 8b) was attributed to the 63% percentage. Then, it was normalised by multiplying it by a coefficient of 0.2. The farm had only agricultural activity. In this case it was attributed the score equal to 0.3 (Figure 8c) which was normalized by multiplying it by a coefficient 0.2. Since there was only one agriculture activity carried out in the farm, there is low resistance to commercial risks (Baccar *et al*., 2019). Finally, the value of diversification index (DI) was 0.52 that turned out to be higher than the sustainability benchmark. The value of index was put on the graphic of sustainability benchmark.

The higher is the value of DI the higher the farm would be resilient to external factors. According to a study carried out by Kazakova-Mateva and Radeva-Decheva (2015), the diversification of crops has a positive impact in increasing the resilience of farms to climate change and environmental pressures. Furthermore, it enhances the technical efficiency in farm, improves their economic results as the results of our study suggest. This is consistent with what was suggested by Baccar *et al*. (2019) and Ogundari (2013) about the fact that the diversification of activities and crops make farms more flexible and resil-

Figure 8 - a) The number of agriculture products realized in the farm; b) Distribution of turnover among different products and services; c) Heterogeneity or affinity of products and services supplied.



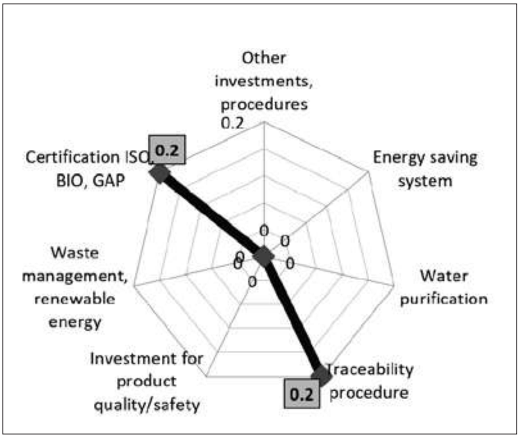
ient. Besides that, it contributes to establishing money reserves which increase thanks to diverse and spread out sources across the year. This flexibility, together with the lack of loans, renders the farm more economically independent.

3.2.2. *Investments or procedures adopted by farm*

Investments or procedures adopted by farm carried out in the last 5 years is 0.3, which turned out to be lower than the sustainability benchmark (Figure 9).

Farmer has invested in the improvement of sustainability performance, but it needs to invest more. However, the farmer has the resources to make larger investments.

Figure 9 - The procedures or investments adopted by the farm.



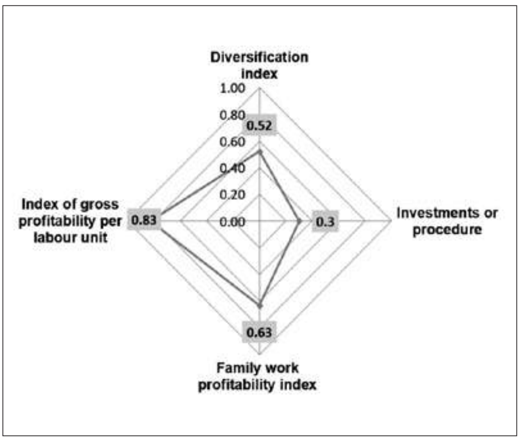
3.2.3. *Family work profitability index*

The updated benchmark for family work profitability index was 19,930 € (ISTAT, 2019) whose attributed score is equal to 0.5.

In the selected farm, the value of family work profitability index was 25,220 € corresponding to the score of 0.63 that turned out to be higher than the sustainability benchmark.

The graphical representation of the sustainability indicator assessment results is illustrated in Figure 10. The sum of the results obtained from the individual indicators provided an economic sustainability indicator whose score was equal to 0.6.

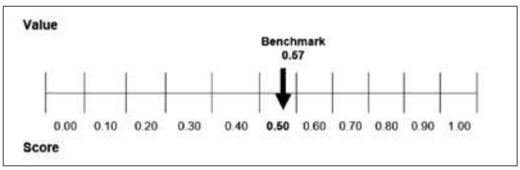
Figure 10 - Assessment of economic sustainability indicators at farm level.



The highest value among the economic sustainability indicators was index gross profitability per labour unit due to high revenue generated in the farm. The lowest sustainability indicator was investments/procedures adopted by farm because of the low number of investments made. It confirms the conclusions from the previous study suggesting that the economic sustainability can be achieved through means of farm investments, as well as low-cost activities that enhance environmental performance and generate positive social effects without damaging economic viability (Majewski, 2013). These investments should not exceed the financing abilities of the farm. The economic sustainability value (0.57) was put on the graphic of sustainability benchmark and it resulted higher than sustainability benchmark (Figure 11).

According to this result, the case study of an organic olive oil farm in the Puglia region is sustainable from economic point of view. Taking into consideration the strong diversity of agricultural farms (e.g. the scale of production, level of technological advancement), this value is moderately good. It should be noted that due to imperfect farmer decisions and competition between sustainability objectives such as economic and environmental, it is practically hard to reach the maximum sustainability value even in the case of a perfect farm as confirmed by Majewski (2013). In this overall frame, factors correlated to the production system and responsibility of farmers (e.g. decisions on what to produce, cropping practices, capital held, etc.) largely determine the economic sustainability farm and, consequently, its sustainability (Baccar *et al.*, 2019). Since the economic sustainability indicator value was above the benchmark sustainability, the traditional organic farm can use the "additional sustainability logo", certified by the Puglia Region during the transitional phase. Additionally, it is stressed that only the "economic sustainability" symbol can be used, instead of the general lettering "sustainability".

Figure 11 - Economic sustainability value.



4. Conclusion

Sustainability is the focus of the CAP. The CAP aims at ensuring sustainability with respect to both economic and social and environmental aspects. The CAP currently offers farmers a number of ways to contribute to our climate and environmental objectives. In the future, the CAP post-2020 will offer more opportunities to farmers in order to create Eco-Schemes for additional incentives for climate and environment-friendly farming practices, as well as for agri-environmental climate measures and investments (European Commission, 2020a).

In order to implement the EU Biodiversity Strategy for 2030 "Bringing nature back into our lives", the agroecology, therefore the organic farming, can provide healthy food while maintaining productivity, increase soil fertility and biodiversity, and reduce the footprint of food production. Moreover, organic farming in particular holds great potential for farmers and consumers alike (European Commission, 2020b). As a matter of fact, the EU Biodiversity Strategy for 2030 highlights, among the key actions, the elaboration and implementation of the Action Plan for Organic Farming for 2012-2026 that proposes a great challenge: at least 25% of the EU's agricultural land must be organically farmed by 2030.

Embedding the concept of sustainability in the way we produce and consume our food will bring benefits for all the actors in the food chain and in particular for farmers (European Commission, 2020c). The economic sustainability of an organic farm is the fundamental issue for the feasibility of the enterprise and the development of organic sector, and moreover, organic agriculture will bring important benefits and positive impacts for the implementation of the aforementioned eco-friendly policies.

The main goal of this study was to investigate the economic sustainability of a case study, a traditional organic olive oil farm in the Puglia region (South-eastern Italy), through the assessment of the economic sustainability indicators selected in the Programme "Agricoltura & Qualità" of the Puglia Region. In this section, the main ideas resulting from economic analysis are listed, followed by the assessment of the economic sustainability of the farm.

The economic assessment through the gross margin showed that the profit of the selected traditional organic olive farm is higher than average gross margin of olive farms of Puglia according to the Rural Development Programme for Puglia 2014-2020. The farm resulted as a profitable enterprise. Profitability differs according to the crops of the farm. Per hectare, the economic assessment showed that almond is the most profitable crop with higher revenue, whereas the variable costs are higher in table olives and the inputs are higher in olives for oil.

Better management of the inputs costs for table olives should be implemented to reduce the production costs and increase the revenues. The use of farm resources and more extensive agricultural practices helps to generate lower production costs. The quantities of nitrogen fertilizer purchased can be moderated through the use of legumes. The mechanized pruning increases the efficiency of labour reducing of the cost of pruning. Furthermore, the use of shakers for mechanized harvesting increases olive production and increases the quality of olive oil, avoiding the harvesting from the ground.

The economic sustainability assessment of the case study in the territorial context using the results economic indicators showed that the selected farm in the Puglia region is sustainable from an economic point of view. In addition, the traditional organic olive oil farm can use the "additional sustainability logo", certified by the Puglia Region, but it can be stressed only through the economic sustainable symbol "economic sustainability" instead of the general lettering "sustainability" since only the economic sustainability of the farm was assessed.

The assessment of the economic sustainability indicators designed in the pilot project reveals that diversification index of organic olive oil farm is higher than sustainability benchmark since the farm produces three different products (e.g. olive oil, table olives and almonds); the first product has a value greater than 63% of the farm production value; and, it has only agricultural activity.

In order to improve the quality of products and sustainability performance, and also to reduce the negative externalities of the production activity, the farmer has invested in PDO, an organic certification and traceability procedure. However, its investments or procedures index is lower than the sustainability benchmark. To increase this indicator and to improve sustainability of farm, the farmer needs to adopt more procedures or make more investments.

The third economic sustainability indicator return rate of family labour is above sustainability benchmark. The last indicator selected from the methodology, namely, the index of gross profitability per labour unit, is higher than the sustainability benchmark.

This assessment tool can support decision-makers in improving the sustainability of their organic production systems.

The SWOT-analysis highlights that Puglia has not a functioning system to ensure sustainability. Sustainability awareness, particularly for consumers and policymakers, is still limited.

It can be concluded that economic sustainability indicators are suitable and measurable at farm level. Most of the data needed to assess sustainability are available.

In this prospect, the suggestions are to foster the implementation of the methodology on a larger scale for economic sustainability, and also for environmental, socio-cultural and health-nutritional dimensions using more human and financial resources, hence, supporting tools to enable an assessment of various scenarios combining technical, economic and environmental indicators. Furthermore, the Puglia Region should invest in sustainability since it is an important opportunity to improve and develop the agri-food system, to fight the economic crisis.

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Using threshold co-integration to estimate asymmetric price transmission in the Turkish milk market

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DOI: 10.30682/nm2101i

JEL codes: C24, D43, L11, Q11

Abstract

We investigate the price dynamics between retail milk price and raw milk price in the Turkish fluid milk market. The study uses monthly fluid milk prices for 14 years between January 2003 and December 2016. We analyze the price adjustment in the fluid milk market through an asymmetric error correction model with threshold co-integration. We find that the transmission between the two prices has been asymmetric in both the long term and short term period. Differences between the farm milk prices and retail milk prices may exist due to marketing costs across the supply chain and pricing policies associated with the market structure. Results of the long-run analysis indicate a significant market power in the fluid milk market. Therefore, in this asymmetric case, the deviations are likely to be the reason for the market power of the processors/retailers and the reason for the oligopolistic market structure in the sector.

Keywords: *Asymmetric price transmission, Error correction model, Threshold co-integration, TAR, M-TAR, Consistent threshold, Fluid milk market, Turkey.*

1. Introduction

Price transmission and market integration have been very important topics in the fields of industrial organization and other areas of applied microeconomics, especially for the study of price relationship in agricultural commodity markets, that can shed light on the stability of prices. With rapidly changing market structures and growing concentration and centralization of processing and retailing firms, the questions of how quickly farm prices are transmitted to the retail level and what the incidence of costs is on retail prices have attracted much attention. Given the price is the primary mechanism in the related markets, the extent of adjustment and speed of shocks transmitted between producer and retailer prices are significant factors showing the behavior of actors at various market levels (Abdulai, 2002). As indicated in Peltzman (2000), asymmetric price transmission is the rule rather than the exception, and various studies have revealed that asymmetric price transmissions are quite common, especially in the agricultural industry.

Price transmission can be defined as the relationship between the prices in the two related

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markets. Price transmission is used to demonstrate the effects of a price change in one market over another and provides information on the extent of these markets. The important issue is whether the transmission is symmetric or asymmetric. A symmetric price transmission integrates markets vertically and horizontally and a change in prices in one market is quickly reflected to another. Therefore, a change in prices in one market will have an equal and immediate effect on the prices in other related market. But, if the price transmission between the specific stages of the supply chain is asymmetric, then the price changes at the production level are not transmitted to the price changes at the processing and/or retailing level quickly or fully as in the case of a symmetric transmission.

There are several reasons for incomplete asymmetric price transmissions (APT); such as asymmetric information among the firms (Bailey and Brorsen, 1989), market power and concentration at processing and retailing levels (Peltzman, 2000; Meyer and von Cramon-Taubadel, 2004; Azzam, 1999), interaction between market power and economy of scale (Lloyd *et al.*, 2006), adjustment and menu costs (Meyer and von Cramon-Taubadel, 2004; Bailey and Brorsen, 1989). Moreover, supply shocks due to adverse weather conditions, and political uncertainty can contribute to high level of prices and the immediate impact would be a fall in the real income of households in real terms (Ghoshray, 2011). Literature on asymmetric price transmission mostly refers to non-competitive market structures such as market power and oligopolistic behavior as an explanation for asymmetry (Vavra and Goodvin, 2005). Brown and Yucel (2000) consider oligopolistic firms engaging in unspoken collusion to maintain higher profits. Ward (1982) suggests that market power can lead to a negative asymmetric price transmission if oligopolists are reluctant to risk their market share by increasing the output prices. Meyer and von Cramon-Taubadel (2004) state that market power can lead to long term asymmetries in the magnitude of adjustment. An important sign of the market power is the existence of price asymmetries which indicate an unbalanced relationship between the price increases and decreases for a product through the farm gate and retail stages. More specifically, price asymmetries could be negative or positive depending on its effect. A positive (negative) price asymmetry occurs when a decrease (increase) in prices at the farm level is not fully or immediately transmitted, but an increase and/or decrease passes more quickly or fully to the final consumer (Meyer and von Cramon-Taubadel, 2004; Vavra and Goodwin, 2005). Price asymmetries are important because, usually, it negatively affects the welfare (Meyer and von Cramon-Taubadel, 2004; Hahn, 1990). In case of vertical asymmetric price transmission, consumers often feel the increasing effect of farm prices that are more fully and rapidly transmitted to retail levels than the equivalent decreases (Kinnucan and Forker, 1987). Similarly, Capitanio *et al.* (2019) investigates asymmetric vertical transmission of price and shows smaller positive effects on consumer welfare and a potential rise in rents for the firms in the Italian hog market. Therefore, we can assume that in case of vertical asymmetries, the value is acquired not in the production stage but inside the supply chain, and that the real winners are not the producers or the consumers (final users), but the holders of the last stage, where the goods are sold to the final consumers.

Price transmission is generally measured by the price transmission elasticity, which is the percentage change in price of one market to a given percentage change in price of another market. If such relationship between two prices exists in the long run, the markets are said to be integrated. This relationship may not hold in the short run due to deviations that can be driven by shocks in one price not being transmitted to the other price. The price transmission elasticity has been estimated by unit root tests and Error Correction Models (ECM) with threshold adjustment (Enders and Siklos, 2001; Meyer and von Crauben-Taubadel, 2004; Frey and Manera, 2007). Threshold adjustment analysis has a particular importance because it implies that movements toward long run equilibrium do not take place at all points in time but only when the divergence from equilibrium exceeds the threshold (Ghoshray, 2011). Abdulai (2002) employs threshold co-integration tests that allow for asymmetric adjustment towards a long-run equilibrium to examine the relationship between producer and retail pork prices in Switzerland. The short-run adjustments are also examined with asymmetric error correction models in the paper. The results show that price transmission between the producer and retail levels is asymmetric. Ghoshray (2002) examines price differentials for the international wheat market by employing a co-integration model with Threshold Autoregressive (TAR) and Momentum Threshold Autoregressive (M-TAR) adjustments and finds that the world wheat market is highly integrated with a little evidence of asymmetry. Jaffry (2004) estimates an asymmetric error correction price transmission model for the whole fresh French hake value chain and tests for the co-integration between auction and retail prices using the Engle and Granger two-step method, the Enders and Granger Threshold Autoregression (TAR) and Momentum Autoregression (M-TAR) methodologies. The results indicate an obvious evidence of asymmetric price transmission in the whole hake value chain. Ghoshray (2008) tests the presence of co-integration within the asymmetric adjustment between the rice export prices of Vietnam and Thailand. The results show that the nature of asymmetry is captured by the M-TAR model and the path of adjustment to the long run equilibrium relation is relatively faster when the price differential is decreasing compared to the case when the price differential is increasing. Ghoshray (2011) tests how international commodity prices are transmitted to domestic prices for 13 country/commodity pairs by using a TAR/M-TAR model and concludes that for the two key commodities, coffee and sugar, there is an evidence of difference-stationary behavior.

Asymmetric price transmission has recently attracted considerably high attention in the agricultural economics. There is a rich literature on the interactions along the dairy marketing chain, on the other hand, existing research has rarely been conducted for Turkey as a developing country of the world where the farm-retail price transmission of fluid milk represents an interesting case as an important food commodity. For instance; Bor *et al.* (2014) finds asymmetry in the Turkish fluid milk market by applying a standard asymmetric error correction model on the monthly prices between January 2003 and December 2012. The results of the paper imply that retailers as well as processors exercise significant market power in the Turkish milk market. Çınar (2017) applies a Vector Error Correction Model (VECM) to monthly price data from January 2003 to December 2016 for farm milk prices and retail cheese and yoghurt prices and finds that there is an asymmetric price transmission between producer and retailer market. Thus, both above mentioned studies support the presence of asymmetric pricing behavior in Turkey. Moreover, Tekgüç (2013) employs Threshold Autoregressive (TAR) and Moment Threshold Autoregressive (M-TAR) models to analyse the relationship between the farm milk prices and wholesale UHT (Ultra-High Temperature) packed milk prices. The author shows evidence for a downward movement in wholesale milk prices while farm gate prices do not decrease correspondingly.

The pricing behaviors in the raw milk market at the farm gate and in the fluid milk market at the retailer shelves are somehow interesting in Turkey. There is a government intervention over the farm gate prices where the National Milk Council makes an announcement to determine a reference price for a raw milk product. In most cases, the reference price is accepted as the ceiling farm gate price in the industry. Also, government subsidizes milk by giving a premium per liter and these payments are done in every three months. For example, the raw milk price was 1.15 TL (0.4356 USD) per liter in April 2015 and there was 0.06 TL (0.0227 USD) premium per liter to the producer. The average retail price was 3.50 TL which was equivalent to 1.325 USD for a daily fluid milk in April 2015 and there was no intervention to the retail prices by any authority. The costs of distribution, processing, and packaging are well defined factors affecting the prices, but still the difference between the farm gate and retail prices may not be easily explained. Farmers at the beginning and consumers at the end of the marketing chain often suspect that imperfect competition in processing and retailing allows middlemen to abuse the market power. This situation raises the questions of how the farm prices are transmitted to the retail price levels if there is an imperfect competition that exists in processing and retailing sectors allowing middlemen to abuse the market power in Turkey. There are empirical studies in literature on asymmetric price transmission referring to anti-competitive market structures (Kinnucan and Forker, 1987; Miller and Hayenga, 2001). These studies investigate imperfect competition in processing and retailing that allows middlemen to use the market power. They generally conclude that monopoly power causes positive price asymmetry (Meyer and von Cramon-Taubadel, 2004). Therefore, we aim to investigate the same issue for Turkey and test raw milk and retail fluid milk price transmissions by employing TAR and M-TAR specifications to contribute to the literature and to provide insights that should signal to policy makers for improving the dairy market structure. Thus, we particularly aim to demonstrate how changes in the prices of one market are transmitted to another, which provides information on the extent of the market and whether markets are operating efficiently. Our focus is on vertical asymmetry in price transmission between different stages of a marketing chain, therefore we estimate the final error correction model of price transmission.

The paper is organized as follows. Section 2 summarizes an overview of the dairy sector in Turkey. Empirical strategy is provided in Section 3. Data, and empirical results are explained in Section 4. Finally, concluding remarks are given in Section 5.

2. Institutional background in the Turkish fluid milk market

In the last decade, dairy-processing industry in Turkey has received a considerable investment, and the number of modern milk processing plants has increased. Many investments on the dairy processing industry have become equipped with high technology, and the result was indeed an increase in the milk production affecting the price of raw milk products. Also, the industry faced with the new labels entering the market, with most of the retail chains producing their own brands and introducing a competition to the other brands in the market. Parallel to this increase in the number of processing firms, the amount of milk produced and processed has also increased in the market. In this respect, there are eight dairy processing or affiliated companies among the top 500 Turkish companies.

Turkey is among the 10 largest milk producers in the world (FAO, 2014). The total annual milk production exceeded 18 billion liters in 2013. In 2013, of the total production, the amount of milk collected by the industry was around 8 million tons and the registered milk production was 46.66% of the total production in 2012 (SIS, 2014). It is estimated that on average 3 billion liters are used by farm families for their own consumption or processing, 1 billion liters are handled by street vendors, over 2 billion liters are processed by *mandira*s (small, simple processing establishments) and well over 3.5 billion liters are processed by medium and large-sized dairies. A significant number of mandiras are run seasonally and they are unregistered. Most of the unregistered milk is handled outside of any formal quality control, unpasteurized and unpacked (Dellal and Berkum, 2009). It is reported that the registered milk production is increased approximately to 50% of the total production in recent years (Turkstat, milk and milk products various years).

The production costs of milk are high in Turkey and raw-milk producers work with low-profit margins due to these high costs. The producer revenue primarily consists of the sales of the milk, and secondarily, the sales of the animals (most dairy farms sell the male calves born by their cows and heifers), making the cost of production undoubtedly important. Therefore, the key determinant of the profit is the cost of the production (DairyCo, 2012). But as the initial investment and production costs are high in Turkey,[1] the level of the raw milk price is significantly important for the farmers. On the other hand, consumption level of liquid milk is very

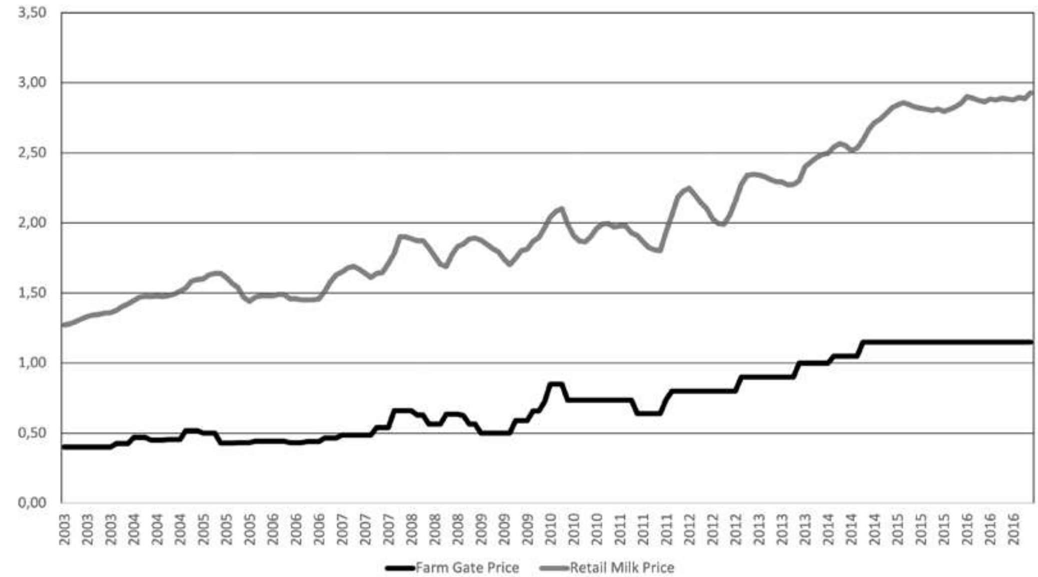
[1] Average production costs consist of around 70% feed, 20% employee and 6% health and surveillance according to Bor, 2014.

low in the Turkish market; the most common form of milk consumption is yoghurt, followed by white cheese (feta type) and ayran, a liquid salted milk drink. The annual per capita consumption of milk in Turkey is 37.3 kg of milk equivalence that is considerably low compared to the other developed countries (FAO, 2014). In 2012, EU-27 had 288.3 kg and North America had 274 kg of milk equivalence (FAO, 2014). The final liquid milk prices on the retail shelves play an important role affecting the consumption level. The consumers argue that the retail price of milk is considerably high in Turkey while the producers argue that the raw milk price is low. Fluid milk market in Turkey is subject to volatile input prices for the producers and volatile final prices for the consumers.

Figure 1 shows that there is a large marketing margin in the Turkish fluid milk market over a long period of time. When we consider the amount of daily milk sold in the market, we see that the margin increases. We also observe that the retail price is being completely unrelated to the farm gate price below a certain threshold.[2] Accordingly, the two prices are related in a nonlinear manner; increases in the farm gate price of the fluid milk (leading to a decline in marketing margins) are transmitted to the retail level rapidly, on the other hand, decreases in the farm gate price of the fluid milk (leading to an increase in the marketing margins) are transmitted to the retail level slowly. If a decrease in farm gate prices is not fully transmitted to retail prices, then reductions in supply and increases in demand, that would have otherwise occurred, will not take place. This would make the price decrease more acute and prolonged. Thus, we can assume that the retailers as well as the processors adjust the prices partly to the changes in demand and supply.

The marketing of the raw milk by the producers is restricted in Turkey such that, the producer

Figure 1 - The farm gate and the retail price of fluid milk (averages of daily and Ultra-High Temperature (UHT) milk together) between 2003/01-2016/12.



Source: Data obtained from Turkish Statistical Institute (Turkstat).

[2] Retail price fluctuations are not thoroughly affected by farm gate price changes and despite the fact that farm gate prices are set fixed at 1.15 TL in 2015, retail prices continued to fluctuate supporting this fact.

and consumer one to one interaction is not available.[3] Therefore, small farmers can only operate through small processors (mandiras) and/or through supplying their production to the big processors.[4] The big processors collect milk by their own cooled trucks and look for suppliers for enough daily raw milk in order to decrease the transaction cost (they are not willing to collect partial quantities). Therefore, only middle and big dairy farms have little bargaining ability for the price and quality (Hatirli, 2004).

The Turkish fluid milk market is highly concentrated. Only few big and traditional brands (SEK, Danone, AOC, Yorsan, Ulker, Pinar) are competing with each other in the market. Although there are new entrants, the market especially has several retailers' own brands in the UHT segment, and the market is still squeezed by the conventional ones. Moreover, in the retail sector, few retailers are spread all over the country although some domestic brands are operating at a regional level. Especially, there are few well known big retailers at the central/crowded cities. Thus, the above mentioned fluid milk brands are dominant on the shelves of these retailers in the country.

3. Empirical strategy

Nonlinearities and asymmetric adjustment are important issues to be addressed. This is true especially when the aim of the model is to take into account a threshold mechanism, which causes a different adjustment to transmission of price signals. We employ the Engle and Granger two step method (1987) to test for the co-integration between the two prices. We assume a symmetric adjustment and use two step methodology to estimate the long run equilibrium relationship. We employ ordinary least squares method to estimate the long run relation which is given by equation (1):

$$RMP_t = \alpha + \beta FGP_t + \mu_t \qquad (1)$$

Here, RMP is the retail milk price and FGP is the farm gate price of fluid milk. RMP and FGP are non-stationary I(1) prices, "α" is an arbitrary constant which accounts for transfer costs and quality differences, "β" is the price transmission elasticity and "μ" is the error term that can be serially correlated. Engle and Granger (1987) show that the co-integration exists if $\mu_t \sim I(0)$. Residuals from equation (1) are used to estimate the following relationship:

$$\Delta\mu_t = \rho\mu_{t-1} + \varepsilon_t \qquad (2)$$

Rejection of the null hypothesis of no co-integration ($\rho \neq 0$) implies that the residuals in equation (1) are stationary.

Enders and Siklos (2001) argue that if the price transmission is asymmetric, then the standard tests for co-integration and its extensions are mis-specified and therefore they consider an alternative error correction specification that is called the Threshold Autoregressive (TAR) model. Recent developments in time series analysis have recognized the potential for threshold type adjustments in error correction models. This issue has been raised in the past literature on agricultural commodity markets but has not been resolved in the case of the fluid milk market in Turkey and therefore deserves a further attention. Previous studies have tried to characterize the nature of the milk market in Turkey. For instance, Hatirli *et al.* (2006) focuses on measuring market power and cost efficiency of

[3] It was forbidden to sell raw milk to the final consumer during our study period. The government announced a notification regarding the supply of raw milk on the 27th of April, 2017 allowing local retailers to supply raw milk to the final consumers. According to this notification, only the institutions which are free from certain diseases are able to supply raw milk once they have a required permission. Moreover, it is necessary to establish a cold chain to keep raw milk in an appropriate environment for product safety and raw milk has to be sold within 48 hours following the first stage of milking.

[4] During our study period, dairy cooperatives are ineffective in terms of their operational activities. These cooperatives mainly establish a cold chain, collect milk from small milk producers and supply these collected milks to milk processors. Recently, there are only two dairy cooperatives actively supplying/marketing milk and dairy products in the market (Tire Milk Cooperative and Agricultural Credit Unions), but their market shares are very limited.

the fluid milk sector in Turkey. They state that Turkish fluid milk market operates under imperfect competition with increased concentration, higher product differentiation, and greater economies of scale. In the case of fluid milk market, the price transmission is likely to be asymmetric in an imperfectly competitive market structure. Given the imperfectly competitive nature of the milk market, we aim to test for the presence of co-integration with an asymmetric error correction across Turkish fluid milk market. Therefore, we follow the Threshold Autoregressive (TAR) and Momentum Threshold Autoregressive (M-TAR) method of adjustment in our empirical strategy to analyze the price dynamics in Turkey (Enders and Siklos, 2001).

Accordingly, when we incorporate this specification (the Threshold Autoregressive (TAR) model) into the equation (2) we obtain,

$$\Delta\mu_t = I_t\rho_1\mu_{t-1} + (1- I_t)\rho_2\mu_{t-1} + \varepsilon_t \qquad (3)$$

I_t is the heavy-side indicator function such that:

$$I_t = \begin{cases} 1 & if \quad u_{t-1} \geq \tau \\ 0 & if \quad u_{t-1} < \tau \end{cases} \qquad (4)$$

where τ is the estimated threshold. This specification allows for an asymmetric adjustment. Here, ρ_1 and ρ_2 represent the speed of adjustment coefficients for RMP_t. The long run equilibrium is given by $\Delta\mu_t=\tau$. If $\rho_1 = \rho_2$, then the adjustment is said to be symmetric. If the adjustment is not symmetric, a negative asymmetry may occur in the series. If $\rho_1 \neq \rho_2$ and $\Delta\mu_t$ is above (under) its long run equilibrium, the adjustment will be given by ρ_1 (ρ_2). Here, the threshold has a particular importance because it implies that movements toward long run equilibrium do not take place at all points in time but only when the divergence from equilibrium exceeds the threshold (Ghoshray, 2011).

In equation (4), the heavy-side indicator depends on the level of μ_{t-1} (Enders and Siklos, 2001). An alternative is suggested by Enders and Granger (1998) and Enders and Siklos (2001) such that, the threshold depends on the previous period changes in μ_{t-1} and μ_t series exhibit more momentum in one direction which is called Momentum Threshold Autoregressive (M-TAR) model. Here, the heavy-side indicator is set by using lagged changes in $\Delta\mu_t$.

$$I_t = \begin{cases} 1 & if \quad \Delta u_{t-1} \geq \tau \\ 0 & if \quad \Delta u_{t-1} < \tau \end{cases} \qquad (5)$$

The consistency of equations (1), (4) and (5) allows us to structure an error correction model as following:

$$\begin{aligned} \Delta RMP_t = {} & \theta + \varphi^+ ECT^+_{t-1} + \varphi^- ECT^-_{t-1} + \sum_{i=1}^{n} \alpha^+ \Delta RMP^+_{t-i} \\ & + \sum_{i=1}^{n} \alpha^- \Delta RMP^-_{t-i} + \sum_{i=1}^{n} \beta^+ \Delta FGP^+_{t-i} \\ & + \sum_{i=1}^{n} \beta^- \Delta FGP^-_{t-i} \\ & + \vartheta_t \end{aligned} \qquad (6)$$

All the lagged prices (RMP and FGP) are split into the positive and negative components as indicated by "–" and "+" superscripts. The error correction terms "ECT" are constructed from the threshold co-integration regressions in equations (3), (4) and (5). The asymmetry in the adjustment speed is checked by defining disequilibrium terms using $\varphi^+ECT^+_{t-1}$ and $\varphi^-ECT^-_{t-1}$. We use $\alpha^+\Delta RMP^+_{t-i}$ and $\alpha^-\Delta RMP^-_{t-i}$, the lagged retail milk price increases and decreases, respectively, and $\beta^+\Delta FGP^+_{t-i}$ and $\beta^-\Delta FGP^-_{t-i}$,the lagged farm gate price increases and decreases, respectively, in order to capture the asymmetries in the short run.

4. Data and empirical results

In this section, we discuss the relationship between market structure and the asymmetric speed of price adjustment in the Turkish liquid milk market. In order to analyze the price asymmetry in the Turkish dairy sector, we use the logarithms of average monthly farm gate milk prices (FGP) and average monthly retail milk prices (RMP) for the period from January 2003 to December 2016. Average monthly retail milk prices are obtained from Turkish Statistical Institute (Turkstat) and monthly farm gate prices are obtained from National Milk Council. As expected, these two variables are likely to be non-stationary.[5]

We estimate the long-run relationship between the two milk prices following the Engle-Granger methodology as specified in equation (1):

$$RMP_t = 0.6732 + 1.8352\ FGP_t + \mu_t \quad (7)$$
$$(34.3258)\ (72.0891)$$

where t-values are provided in parentheses.

In Table 1, the residual is used to conduct a unit root test with the specification given in equation (7) in the form of Engle-Granger, TAR, TAR consistent, M-TAR and M-TAR consistent models. We use the thresholds, $\tau = 0$ for TAR, τ=-0.0766 for TAR consistent, $\tau = 0$ for M-TAR, and τ = -0.040 for M-TAR consistent. In estimating the threshold values for consistent TAR and M-TAR, we follow the methodology introduced by Chan (1993). We choose 2 lags depending to Akaike criterion (AIC) statistics and we also find that different lag specifications in the models have little impact on the final threshold values selected.

Table 1 - Results of the Engle-Granger and threshold cointegration tests.

Item	*Engle-Granger*	*TAR*	*Consistent TAR*	*M-TAR*	*Consistent M-TAR*
Estimate					
Threshold(τ)	NA	0	-0.077	0	-0.040
ρ_1	-0.208***	-0.133**	-0.107*	-0.149**	-0.148***
	(-4.255)	(-2.174)	(-1.941)	(-2.109)	(-2.852)
ρ_2	NA	-0.310 ***	-0.429***	-0.251***	-0.481***
		(-4.3753)	(-5.421)	(-4.032)	(-4.503)
γ_1	0.046	0.059	0.100 ***	0.048***	0.136
	(0,582)	(0.762)	(1.294)	(0.616)	(1.633)
γ_2	0.147*	0.149*	0.171**	0.139*	0.123
	(1.890)	(1.942)	(2.265)	(1.788)	(1.602)
AIC	-150.425	-152.392	-160.430	-149.707	-156.619
Φ	NA	11.178***	15.754***	9.698**	13.556***
ρ_1=ρ_2[a]	NA	3.9177	3.917	1.255	8.197
		[0.049]	[0.001]	[0.264]	[0.005]

Parentheses are the t statistics.

Φ is the F statistics with the null hypothesis $\rho_1=\rho_2=0$ with critical values from Wane et al. (2004).

[a] *Entries are the sample F statistics for the null hypothesis that the adjustment coefficients are equal. P-values are provided in square brackets.*

Three, two and one asterisks (*) denote that the estimated coefficient is statistically significant at, or below, one, five, and ten percent level, respectively.

[5] Dickey-Fuller unit root test results are 0,3813 for RMP and -0,1859 for FGP with critical values of -3.4731 for 1%, -2.8799 for 5% and -2.5765 for 10%.

As shown in Table 1, the t statistics for the coefficient of μ_{t-1} equals -4.255. Thus, the Engle-Granger test confirms that the two price series are co-integrated at 1% level. The nonlinear co-integration analysis is conducted using the threshold autoregression models. The estimated residuals of equation (7) in the form of TAR, TAR consistent, M-TAR and M-TAR consistent models are given in Table 1. The sample value of TAR, TAR consistent and M-TAR consistent models are significant at 1% level, M-TAR model is significant at 5% level and Φ (F) statistics indicate that two series are co-integrated. The null hypothesis that the adjustment coefficients are equal ($\rho_1=\rho_2$) is also rejected for TAR, TAR consistent and M-TAR consistent models. The equality of adjustment coefficients is not rejected only in M-TAR model. Conducting a model selection test, that is the Akaike criterion, we conclude that the TAR consistent model is appropriate one to be selected. Therefore, model estimation results suggest that the TAR consistent model detects the asymmetry better than the other models.

Thus, these results indicate an asymmetric adjustment and suggest that the retail and farm gate prices are co-integrated in Turkey. The values of the adjustment parameters (ρ_1 and ρ_2) have the correct signs and suggest the convergence. But the estimates also suggest that decreases in farm gate prices are eliminated more quickly compared to the price increases. Positive deviations in the long-term equilibrium resulting from increases or decreases in the prices ($\mu_{t-1}\geq-0.077$) are eliminated at a rate of 10.7% per month. Negative deviations in the long-term equilibrium resulting from increases or decreases in the prices ($\Delta\mu_{t-1}<-0.077$) are eliminated at a rate of 42.9% per month. In other words, positive deviations take about 9 months (1/0.107=9.34 months) to be fully digested whereas negative deviations take about 2 months (1/0.429=2.33) to be fully digested. Therefore, there is a substantially slower convergence for positive (above threshold) deviations from long-run equilibrium compared to negative (below threshold) deviations.

The evidence of an asymmetric co-integration leads to the estimation of the ECM with long-run asymmetric equilibrium. Long-run adjustments are allowed to differ depending on the previous period changes in the long-run error terms. The model of co-integration with TAR consistent adjustment justifies estimation of the error correction model as specified in equation (6).[6] We estimate the asymmetric error correction model with threshold co-integration and our results are given in Table 2.[7]

Three, two and one asterisks (*) denote that the estimated coefficient is statistically significant at, or below, the one, five, and ten percent level, respectively (the results are based on Newey-West standard errors).

Table 2 - Results of the asymmetric error correction model with threshold co-integration.

Item	*Estimate*
Θ	0.004 (1.903)*
α_1^+	0.581 (5.020)***
α_2^+	-0.077 (-1.615)
α_1^-	0.659 (2.955)***
α_2^-	-0.402 (-1.119)
β_1^+	0.136 (1.259)
β_2^+	-0.045 (-0.391)
β_1^-	0.557 (2.454)**
β_2^-	0.183 (0.681)
φ^+	-0.088 (-3.434)***
φ^-	0.015 (0.113)
R^2	0.549
AIC	-319.257

Note: t-values are provided in parentheses.

[6] The Granger theorem (Engle and Granger, 1987) indicates that an error correction model can be estimated where all the variables are co-integrated with the assumption that the adjustment process due to disequilibrium among the variables is symmetric. For analyzing asymmetric price transmission, Granger and Lee (1989) decompose error correction terms and first differences on the variables into positive and negative components. In this way, it is possible to know whether positive and negative price differences have asymmetric effects on the dynamic behavior of prices.

[7] Furthermore, the hypotheses of Granger causality between the two prices are assessed with F-tests (not reported in the paper). The F-statistic of 12.8617 and the p-value of 0.0000 reveal that the price of raw milk does Granger cause the price of retail milk.

As seen from Table 2, the short run coefficients α^* and β^* suggest the presence of price symmetries. Wald tests also confirm this result.[8] The point estimates of the coefficients for the error correction terms are -0.88 for the positive error correction term (significant at 1%) and 0.015 for the negative error correction term that is also significant. Therefore, we see that in the short term the price of milk has some different responding speed to positive and negative deviations but the difference is weak for the negative ones. This result may suggest that a threshold specification of the long-run mechanism provides a more plausible representation of the farm gate and retail price relationship.

The insignificant φ^- and significant φ^+ suggest that raw milk price increases adjust while price decreases do not adjust in the long run. We also note that the speed of adjustment terms (φ^+ and φ^-) are usually sensitive to the sample period and may have poor small sample properties (Enders and Siklos, 2001). Thus, the corresponding Wald test result has not shown asymmetry for the speed of adjustment terms for error-correction models based on TAR consistent model.

5. Conclusion

This paper examines the extent to which increases and/or decreases in farm gate prices during the past years have been transmitted to retail level prices for an important food commodity, fluid milk, in Turkey as a developing country. In this study, we particularly examine the price transmission between raw milk and retail milk markets using the threshold co-integration. We also analyze the price adjustment in the short term through an asymmetric error correction model with a threshold co-integration. The motivation of our research on price transmission is to reveal whether prices are integrated since co-movement of prices in different markets can be interpreted as a sign of efficient markets, while the absence of price co-movement can be viewed as a sign of market failure. Therefore, we aim to determine whether any causal relationships exist among prices in the Turkish fluid milk market.

Our results report the price relationship between these two fluid milk markets over the fourteen years. Accordingly, the transmission between the two prices has been asymmetric in both the long term and short term period of time. The threshold co-integration analysis reveals that in the long term positive deviations of the price spread between the two markets take about 9 months to be fully digested, while negative deviations take about 2 months. Thus, the results state that the nature of asymmetry is captured by the TAR model which suggests that the path of adjustment to the long run equilibrium relation is relatively faster when the price differential is decreasing compared to the case when it is increasing.

Differences between the farm and retail milk prices can exist due to marketing costs across the supply chain and pricing policies associated with the market structure. But, when we look at the long-run relationship between farm gate and retail prices (equation 7), 1 Turkish Lira increase in the farm gate price increases the retail milk price by 1.84 Turkish Lira. This result may indicate a significant market power in the Turkish fluid milk market. Therefore, in this asymmetric case, the deviations can be the reason of the market power of the processors/retailers and the reason of the oligopolistic market structure in the sector.

In Turkey, producers are subject to various restrictions for marketing of raw milk and government intervenes to raw milk prices, therefore the processors/retailers have an unequal bargaining power over the producers. Moreover, producers keep their raw milk products in the cooling tanks, where it stays fresh only for a few days, thus they need to be sold within a short period of time. As the processing industry is concentrated and the structure of unions and cooperatives are ineffective, the producers of raw milk work under contracts and inevitably they have a little bargaining power over the processors.[9] This implies that the farm price of milk is mainly de-

[8] Wald test results (not reported) can be provided upon request from the authors.

[9] Collected milk by the industry (registered milk production) is around 50% of the total production (Turkstat, milk and milk products various years).

termined by the industry, due to a little market power of the farmers. On the consumption side, the milk can stay fresh for several months on the shelves in UHT (Ultra-High Treatment) packets causing processors/retailers to benefit from a greater elasticity compared to producers. Also, there is no government intervention to the fluid milk market on the consumption side and the prices on the shelves are freely determined.

There is only a small number of big and traditional brands (SEK, Danone, AOC, Yorsan, Ulker, Pinar) in the Turkish milk market and the market structure is highly competitive. The improvements in the UHT technology enable firms to operate with stocks. Therefore, there is a high level of competition in the retailers' shelves. Also, as stated above, there is a big mark-up in pricing the fluid milk products. Therefore, the firms/brands react immediately to price decreases in raw milk and easily transmit the price decreases to their final products. But it is not the case for price increases; the firms/brands do not react quickly to price increases in raw milk products. The profit margin is high enough to compensate the increases in raw milk prices, so the deviation is much slower. This result is consistent with Ward (1982) stating that the market power can lead to negative asymmetric price transmission if oligopolists are reluctant to risk their market share by increasing output prices. Thus, the price response behavior of retailers is found to be consistent with asymmetric price transmission. These findings have profound implications for studying margins along the fluid milk market, therefore ignoring the asymmetry in price transmission is likely to cause calculations of margins to be biased.

In summary, Turkey has the opportunity to improve the dairy sector and to achieve modern standards in the means of production and structure of dairy farms. But the problem arises firstly from the high cost of production (low farm gate prices) and secondly from the high fluid milk prices on the shelves. The effects of high prices on households make it necessary for policy makers to know whether and to what extent farm prices are transmitted to retail prices and its impact on the economy. In the Turkish dairy farms, small farmers face many difficulties for satisfying the capital requirements of buildings and improving a dairy farm structure, and therefore effective marketing and production agricultural cooperatives can be organized to maintain a better market strategy. Moreover, the producers can gain a bargaining power over the processors and also can reach to final consumers directly. This may help to depreciate the power of the processors and the retailers over the producers and consumers improving the production and consumption of milk in Turkey. Finally, we hope that findings reported here will give directions for future qualitative and quantitative studies in Turkey that will systematically guide policy makers to build reforms and regulations improving the fluid milk market structure.

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Printed in Italy
March 2021

NEW
MEDIT
MEDITERRANEAN
JOURNAL OF ECONOMICS,
AGRICULTURE AND
ENVIRONMENT

CIHEAM
BARI

ISBN 978-88-6923-768-3
9 788869 237683