Technical efficiency of olive oil firms under the industrial upgrading programme in Tunisia

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Jel classification: O12, O13, O14

Abstract

This paper investigates firm-level technical efficiency of olive oil producers in Tunisia under the industrial upgrading programme (programme de mise à niveau: PMN). Using a sample of 113 olive oil firms, the translog type of stochastic frontier production function was estimated. Results suggest that the introduction of modern technology, employment of management staff and in-house production of olives contribute to improved technical efficiency. These results confirm the pertinence of the PMN which promotes the use of modern technologies and the introduction of the continuous chains system for olive oil extraction; however, development of in-house production of olives could contribute to improving quality of olive oil product.

Keywords: *Olive oil; stochastic frontier production function; technical efficiency; in-house production, Tunisia.*

Résumé

Ce travail analyse l'efficacité technique des entreprises productrices d'huile d'olive en Tunisie sous le Programme de mise à niveau (PMN). En utilisant un échantillon formé par 113 entreprises productrices d'huile d'olive, on a estimé une fonction de production stochastique du type translog. Les résultats obtenus suggèrent que l'utilisation des technologies modernes, le fait d'avoir des cadres en management, et l'autoproduction d'olives améliorent l'efficacité technique de l'entreprise. Ces résultats confirment la pertinence du PMN qui soutient l'utilisation de technologies modernes et l'introduction du système de chaîne continue d'extraction d'huile d'olive. Cependant, l'autoproduction d'olives pourrait contribuer à l'amélioration de la qualité du produit.

Mots clés: Huile d'olive, fonction de production stochastique, efficience technique, autoproduction, Tunisie.

1. Introduction

Tunisia is the world's third-largest exporter of olive oil during the period 2014/15 after Italy and Spain. Tunisia's production of olive oil accounted for 260,000 tonnes and its export amounted to 170,000 tonnes in 2014/15[1]. However, the olive oil sector in Tunisia has faced difficult times since the mid-1990s. One factor is the increasing pace of liberalization since the country's accession to the World Trade Organization (WTO) in 1995. Another factor is the agreement with EU under the framework of the Euro-Mediterranean Partnership launched during the mid-1990s. This agreement requires the Tunisian agro-food sector, which includes olives and olive-oil production, to open its markets and join the EU-Mediterranean free trade area. In the face of growing international competition, the Tunisian government put in place the industrial upgrading programme (programme de mise à niveau: PMN) in 1996 as part of the liberalization process (World Bank, 2009). This programme aims at improving the competitiveness of the manufacturing sector to meet the new challenges posed by the accession of Tunisia to the WTO and European partnerships.

A whopping 90% of Tunisian firms are small and medium enterprises that are largely family-owned (World Bank, 2009). To prepare them for a more liberal and competitive environment, substantial financial support has been made available through a dedicated fund aimed at improving industrial competitiveness. The upgrading process has two components: physical investment in machinery modernisation and laboratory equipment, and intangible investment in the form of training and capacity building, mainly for quality control and the adoption of the ISO or European quality schemes. This upgrading programme is run in conjunction with the Industrial Modernisation Programme (IMP), which was launched in 2004, supported by EU under the MEDA programme for the implementation of the EU-Med partnership (Zaibet, 2007; World Bank, 2009).

Olive oil production, the first agro-food export sector, was among the first sectors to be served by PMN. Despite its increasing importance, few studies have investigated the productivity and technical efficiency of this sector. Regarding the analysis on technical efficiency of olive production in Tunisia, Lachaal *et al.* (2005) estimated the level of technical efficiency of olive-growing farms using cross-sectional data. The study focused on the relatively low level of technical efficiency scores as well as their determinants – small farm size, large number of farm plots and scarcity of

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[1] See World Olive Oil Figures, International Olive Council <http://www.internationaloliveoil.org/ estaticos/view/131-world-olive-oil-figures> (accessed: 1 December, 2015).

skilled labour and training. By collecting panel data, Tzouvelekas *et al.* (1999) surveyed the olive production of Greek farmers to show how factors of production affected technical efficiency and technological change. Tzouvelekas *et al.* (2001) compared the technical efficiency of organic olive-growing farms with those of conventional farms in Greece, and found slightly higher technical efficiency on organic farms, relative to their production frontier, than conventional ones[2].

Although many studies have investigated technical efficiency at the farm level (olive production), there are, to our knowledge, only two studies that focused on olive oil production. The first is by Damas and Romero (1997), who analysed the technical efficiency of olive oil producing cooperatives in Jaén (Andalusia). They found that technical efficiencies varied by periods as well as between and within cooperatives. Decisions on the development of cooperatives and their financial policies had a significant impact on their technical efficiencies. Moreover, Spain's admission into the EU economy had a positive effect on the efficiency of cooperatives. A subsequent study by Dios-Palomares and Martínez-Paz (2011) examined technical efficiency in production, quality and the environmental management of the olive oil sector in Andalusia (Spain) by applying the nonparametric approach. The study showed a medium to high level of relative technical efficiency (84.8%), and highlighted the importance of efficiency factors in production and marketing associations for achieving production quality and for environmental management purposes. Both studies employed the data envelopment approach (DEA) for estimating the level of technical efficiency of olive oil producers; however, sources of technical inefficiency were not identified by applying the parametric approach.

To the best of our knowledge, this paper is the first attempt to examine technical efficiency of olive oil production in Tunisia. In addition, it would be valuable to have a baseline estimated in the initial stage for the efficiency scores. Given the aforementioned PMN, an assessment of improvement in technical efficiency would provide useful insights into their efficacy and on future steps and decisions. Hence, this paper investigates technical efficiency at the firm level for olive oil producers in Tunisia, using a stochastic frontier production function with technical inefficiency effects. The objective is to estimate the level of technical efficiency and identify the sources of efficiency in the production of olive oil during the implementation of the PMN.

[2] Most other studies focused on the functioning, profitability and marketing of the olive oil in its value chain without empirically estimating technical efficiency (Sanz-Cañada and Macías-Vázquez, 2005; Mili, 2006; Sanz-Cañada *et al.*, 2015).

[3] See FAOSTAT < http://faostat.fao.org/> (accessed: 1 December, 2015).

[4] See the Industrial Upgrading Programme (programme de mise à niveau), Ministry of Industry, Republic of Tunisia <http://www.pmn.nat.tn/> (accessed: 2 April, 2016).

The remainder of the paper is organized as follows. In Section 2, we review the Tunisian olive oil sector. The methodology of the stochastic frontier model is elaborated in Section 3. In Section 4, we examine the data collection process. Empirical results are presented in Section 5. Based on the empirical results, we extend discussions in Section 6. Section 7 concludes the paper.

2. Olive oil sector under the industrial upgrading program

Production of olives comprises an important part of the Tunisian agro-food sector, accounting for 41.1% of the total harvested area and 15.1% of agricultural production in 2012[3]. The olive oil sector contributes to Tunisian socio-economic development by providing 40 million working days per year (20% of agricultural employment) and mitigating an exodus from the rural to urban areas by employing the rural population. The olive oil sector, either directly or indirectly, employs over 1 million people and 269,000 farmers are dedicated to growing olives (Angulo *et al.*, 2011).

Olive oil is a major export product of Tunisia. FAO statistics of 2011 shows volume of its export accounted for 18.6 million US dollars, representing 18.1% of the total export of agricultural products. As noted, Tunisia is the third-largest exporter of olive oil; however, these exports are mainly directed to Italy, Spain and USA. In fact, 97% of Tunisian olive oil export is still traded unbranded and in bulk (World Bank, 2009, Karray and Kanoun, 2013), with a large proportion of it forming part of the olive oil contingent free-trade agreement signed by Tunisia and EU. The Tunisian government sought to increase bottled olive oil exports, specifically extra virgin olive oil, to reach 10% of their total exports by 2010. However, this goal has not been achieved; only 2% to 3% are actually exported in bottles. The aim of increasing bottled olive oil exports is to generate higher value added and establish a presence in overseas markets with the bottles having an original Tunisian label.

The Tunisian government launched PMN in 1996 to improve the competitiveness of the manufacturing sector and meet the new challenges of the accession of Tunisia to the WTO and European partnerships. PMN forms part of a series of other national upgrading programmes initiated by the Tunisian authorities in the mid-1990s to re-adjust the economy. At the end of October 2015, approximately 5,289 companies had participated in PMN, with a total investment amount of 9,039 million Tunisian dinars (TND)[4]. The mechanical and electrical industry and the agro-food sector account for the largest investments, representing 19.5% and 19.0% of total investment, respectively. In the agro-food sector, physical investment, which consists of equipment and machinery modernisation, represents 92% of the total investment. The remaining 8% (148 million TND) were allocated to intangible investments in the form of employee training and capacity building, mainly for quality control and the adoption of ISO or the European quality schemes.

Regarding the olive oil sector, specifically olive oil producers at the end of 2010, the upgrading programme permitted the participation of approximately 140 firms. Nevertheless, only two companies were certified with ISO 9002.

Improving product quality is an important factor in increasing Tunisian olive oil competitiveness in local and foreign markets. The proportion of extra virgin olive oil (higher quality) exports is increasing compared with ordinary virgin olive oil. It represented 56% of the value of total Tunisian olive oil exports in 2008. To improve product quality, the Tunisian government supported olive oil producers (through the fund for improvement of industrial competitiveness) to improve the extracting processes and capacities by upgrading the machinery and facilitating the adoption of new technologies. The number of modern olive oil mills, such as continuous chains, has increased substantially over the past 15 years, leading to a national extracting capacity of 41,500 tonnes per day, three times greater than the triturating capacity of the 1980s.

The Tunisian olive oil producing system is composed of three coexisting olive oil extracting systems: the traditional method, the super-press and the continuous chains (the modern method). A few olive oil mills have more than one type of processing unit; these mills are called mixed units. According to the Ministry of Agriculture and Hydraulic Resources in Tunisia, there were 1,725 olive oil mills in 2010, of which 628 were traditional units, 388 were super-press units and 709 continuous chains. These figures suggest the rate of diffusion of the continuous chains is around 41%. According to the World Bank (2009), olive oil extraction in Tunisia with modern equipment currently represents 31%. In contrast, it is 70%-80% in Italy, Greece and Spain. Thus, although the government is promoting the number of continuous chains, Tunisia's remains the lowest of the four main olive oil producers and exporters.

3. Methodology

Following the seminal paper by Farrell (1957), stochastic frontier production function (SPF) was introduced by Aigner *et al.* (1977) and Meeusen and van don Broeck (1977). Jondrow *et al.* (1982) extended the SPF to allow for the estimation of individual firm efficiency levels with cross-sectional data. Techniques to estimate efficiency scores range from the non-parametric approach to the statistical frontier or parametric approaches. The non-parametric approach, initially proposed by Farrell (1957), gained through the developments by Charnes, Cooper, and Rhodes (CCR) and others. This approach is called the data envelopment analysis (DEA) approach (Charnes *et al*., 1978). On the other hand, the parametric approach and its technique were developed by Richmond (1974) and Greene (1980). Kumbhakar *et al*. (1991) used system approaches and proposed a one-stage procedure to estimate efficiency measures along with their determinants. This approach has been widely used and made more popular due to the development of computer applications, namely Frontier (Coelli, 1996).

Given the above, we adopt the Battese and Coelli (1995) model of the SPF, but in the context of cross-sectional data.

$$y_i = f(x_i;\beta)e^{v_i - u_i}, \tag{1}$$

where y_i denotes output for the *i*th firm; β is a vector of unknown parameters to be estimated; x_i is a vector of inputs of production and other explanatory variables associated with the *i*th firm; v_i refers to statistical random disturbance terms, assumed to be independently and identically distributed $N(0, \sigma_v^2)$; u_i represents non-negative random variables, assumed to be independently and identically distributed as truncation at zero of the normal distribution with mean $m_i = \delta' z_i$, i.e., $u_i \sim$ iid $N^+(m_i, \sigma_u^2)$.

In this specification, $(-u_i)$ measures the distance between the realized output and the frontier output. The exp $(-u_i)$, which varies between 0 and 1, is a measure of the technical efficiency of the *i*th firm. Following Battese and Coelli (1995), the technical inefficiency effect, u_i, in the stochastic frontier model (1) could be specified in Equation (2):

$$u_i = \delta' z_i + w_i \tag{2}$$

where δ is a vector of the unknown parameters to be estimated; z_i is a vector of explanatory variables associated with technical inefficiency in production; w_i is a random variable, defined by the truncation of the normal distribution with zero mean and variance σ_w^2, $N(0, \sigma_w^2)$, such that the point of truncation is $-\delta' z_i$, i.e., $w_i \geq -\delta' z_i$. The technical efficiency of production of the *i*th firm can be defined as:

$$TE_i = \exp(-u_i) = \exp(-\delta' z_i - w_i) \tag{3}$$

In this study, the following translog functional form is used for the estimation of the SPF:

$$\ln y_i = \beta_0 + \sum_{j=K}^{M} \beta_j \ln x_{ji} + \frac{1}{2}\sum_{j=K}^{M}\sum_{k=K}^{M} \beta_{jk} \ln x_{ji} \ln x_{ki} + v_i - u_i, \tag{4}$$

where

$$u_i = \delta_0 + \sum_{h=1}^{H} \delta_h z_{hi} + w_i. \tag{5}$$

The subscript *i* refers to the *i*th firm; *j* and *k* represent inputs applied to olive oil production ($j, k = K, L, M$); y_i denotes the quantity of output for the *i*th firm measured in tonnes; x_{Ki} is the capital stock of the *i*th firm in TND; x_{Li} is total hours of labour devoted to olive oil production by the *i*th firm; x_{Mi} is volume of intermediate inputs for the production measured in TND. In equation (5), $h = 1, 2, \ldots, H$ are the firm-specific efficiency related variables.

The model of technical inefficiency effects is defined as follows:

$$u_i = \delta_0 + \delta_1 D_{MSi} + \delta_2 D_{TECi} + \delta_3 SOP_i + \delta_4 D_{Ni} + \delta_5 D_{Si} + w_i, \tag{6}$$

where D_{MS} is the management dummy variable that equals 1 if the firm employed management staff for accounting, supplying, or marketing, and zero otherwise; D_{TEC} is a dummy variable that equals 1 if the firm adopted modern technology in oil extraction process, and zero otherwise; *SOP* represents the ratio of supply of olives from in-house production; D_N, D_S are dummy variables representing the north and south regions, respectively. The variable of choice of modern technology, D_{TEC}, represents captures the effect of PMN that promotes the introduction of modern extraction method and equipment. The parameters of the SPF in Equation (4) and the model for technical inefficiency effects in Equation (6) are simultaneously estimated by the maximum likelihood (ML) model (Reifschneider and Stevenson, 1991; Huang and Liu, 1994).

The typical statistical issues that have to be solved in this model are selectivity and/or endogeneity involving the choice of supplier of olives and extraction technology. The decision whether relying on the supply of olives from his/her own farm land or collecting from outside, *SOP* is a choice variable and thus might be correlated with the error term in equation (6)[5]. Since we consider these variables are endogenous, an instrumental variables (IV) technique is used to correct for the bias caused by endogenity. For the decision to rely on in-house production (*SOP*), a dummy variable of traditional method, D_{TRD}, which equals 1 if the firm employed traditional method of oil extraction process, and zero otherwise; share of skilled labour to total employees, *SKL*; ratio of supply of olives from same governorate, *SOS*, were used as instrumental variables. These variables were used as a set of explanatory variables to estimate the first step of auxiliary regression model. Because of its statistical characteristics of the dependent variable, we estimate an auxiliary regression by OLS. Consequently, the Two-Stage Least Squares (2SLS) method is employed. The variables included in the inefficiency effects model are the expected value obtained from the estimation of these auxiliary regressions.

4. Data collection

The data used in this study is drawn from a survey conducted in February and March 2009. The questionnaire was sent directly to directors or managers of olive oil production units. The selected units were located in the north, centre and south of the country. The targeted governorates included Zaghouan from the north, Sousse and Mehdia from the centre and Sfax from the south. In accordance with the distribution of olive oil manufactures by the Directorate General for Agricultural Production (DGPA), Ministry of Agriculture in Tunisia, these four governorates were chosen in each region as major areas where olive oil manufactures locate. According to the data by DGPA, olive oil firms in these selected governorates represents 50.0% of total olive oil manufactures and contributes 46.0% of national triturating capacity. In these governorates, the random survey was conducted, and 137 samples were collected in total. The olive oil firms were randomly selected from each region, and the number of questionnaires completed was 45, 43 and 49 in the north, centre and south of Tunisia, respectively. According to the DGPA, the number of olive oil producers in 2009/10 was 222, 857 and 655 for the northern, central and southern regions, respectively. Thus, the coverage of this survey was around 8%. Our analysis is based on the sub-sample of 113 firms, 82.5% of the sample, which reported producing extra virgin olive oil. Thus, the sample actually used in the analysis consists of a random sub-sample of 113 producers from 34, 43 and 36 in the north, centre and south of Tunisia, respectively, representing 6.5% of the national establishment. As noted, the number of olive oil producers which participated in PMN was 140 in 2010, representing 8.07% of total. Consistently, our sample includes 9 firms operating under PMN (7.96% of the sample).

Table 1 shows the summary statistics for the variables. The average annual production of the sample firms ranges from a minimum of 10 tonnes to a maximum of 1,200 tonnes, with a mean value of 296 tonnes. The table also indicates that sample firms employ 15,200 hours per year on

Table 1 - *Summary statistics of the sample.*

Variables and measurement	Mean values	Standard Deviation	Maximum	Minimum
y: Production of extra-virgin olive oil (tonnes)	296.3	240.8	1200.0	10.0
x_K: Capital stock (thousand TND)	357.7	241.4	1380.5	43.0
x_L: Total hours of labour used (thousand hours)	15.2	10.2	80..6	3.6
x_M: Intermediate inputs (thousand TND)	1506.3	1288.1	8041.0	64.9
D_{MS}: Dummy of management staff (1: employ managmemnt staf for accounting, supplying or marketing, 0: otherwise)	0.398	0.492	1	0
D_{TEC}: Dummy of modern technology (1: adopt modern technology in oil extraction process, 0: otherwise)	0.850	0.359	1	0
SOP: Ratio of supply of olives from in-house production to total	0.061	0.108	0.800	0.000
D_N: Location dummy (1: locate in norhern region, 0:otherwise)	0.301	0.461	1	0
D_S: Location dummy (1: locate in southern region, 0:otherwise)	0.319	0.468	1	0
D_{TRD}: Dummy of traditional method (1: employ traditional method in oil extraction process, 0: otherwise)	0.044	0.207	1	0
SKL: Ratio of skilled labour to total employee	0.207	0.096	0.500	0.000
SOS: Ratio of supply of olives from same governorate to total	0.579	0.257	1.000	0.000

(Note) TND indicates Tunisian Dinar.

[5] Our endogeneity assumption is supported by the Durbin-Wu-Hausman test. In the right-hand-side (RHS) variables of the inefficiency model, the possible endogeneity may be identified in the variables of D_{TEC} and *SOP*. Following the Durbin-Wu-Hausman test, we firstly run an auxiliary regression of possible endogenous variables on all other RHS variables of the original inefficiency model, plus a set of instrumental variables (Davidson and MacKinnon, 1993; Wooldridge, 2002; Saldias and von Cramon-Taubadel, 2012). Second, the equation (4), simultaneously equations (6), are estimated including the residuals of the auxiliary regression as an additional RHS variable in the inefficiency model. Under the null hypothesis of no endogeneity, the coefficient of this additional residual term equals zero. While the null hypothesis that the residual estimated by the equation which endogenized D_{TEC} is insignificant was not rejected, the null for *SOP* was rejected.

average, 20.7% of which consist of skilled employees. While 96 firms evaluated their level of technology as modern, 17 firms deemed it traditional. The sample includes 45 firms that employ management staff. The average ratio of olives supplied from own farmland is 0.06, where 39.8% of the sample (45 firms) depend their inputs of olives on in-house production.

5. Empirical results

ML estimates based on the translog stochastic frontier production model and technical inefficiency effects model are obtained using the Frontier 4.1 package (Coelli, 1996). Table 2 shows the estimates of the parameters and corresponding *t*-values. In the model corrected for endogeneity, the expected value of *SOP* obtained from the estimation of the auxiliary regression was used for the estimation of the inefficiency model. Comparison of the estimated coefficients with and without the correction for endogeneity reveals few changes; however, most coefficients retain their original signs and levels of significance. The signs of the estimated parameters are as expected, except for the intermediate inputs. The estimated coefficients of the capital stock and labour input are positive and statistically significant. These results indicate a positive relationship between the input of capital and labour inputs and the production of extra virgin olive oil. The negative coefficient of the intermediate inputs is not significant.

Table 2 - *Parameter estimates and t-values of the stochastic frontier and inefficiency effects models.*

Variables	Initial model		Model corrected for endogeneity	
	Coefficient	*t*-values	Coefficient	*t*-values
Stochastic frontier model				
Intercept	-24.364 ***	-11.900	-24.131 ***	-9.478
$\mathrm{Ln}X_K$	3.242 ***	3.074	2.820 ***	2.827
$\mathrm{Ln}X_L$	1.893 **	2.100	1.831 **	2.023
$\mathrm{Ln}X_M$	-0.852	-0.989	-0.462	-0.587
$\mathrm{Ln}X_K{}^2$	0.104	0.693	0.111	0.764
$\mathrm{Ln}X_L{}^2$	-0.556 **	-2.362	-0.482 **	-2.133
$\mathrm{Ln}X_M{}^2$	0.219 *	1.686	0.198	1.529
$\mathrm{Ln}X_K\mathrm{Ln}X_L$	-0.019	-0.170	-0.018	-0.160
$\mathrm{Ln}X_K\mathrm{Ln}X_M$	-0.307 ***	-2.684	-0.283 **	-2.513
$\mathrm{Ln}X_L\mathrm{Ln}X_M$	0.264	1.561	0.219	1.344
Inefficiency effects model				
Intercept	-3.767 *	-1.664	-4.234	-1.497
D_{MS}	-0.620 **	-1.970	-0.536 *	-1.805
D_{TEC}	-1.005 ***	-2.854	-1.058 ***	-3.092
SOP	-2.402 **	-2.084	-3.695 ***	-2.810
D_N	3.417 *	1.746	3.550	1.463
D_S	5.838 **	2.483	6.071 **	2.134
Variance parameters				
σ^2	0.569 ***	4.117	0.620 ***	3.670
γ	0.896 ***	25.404	0.903 ***	23.120
No. of observations	113		113	
Log-likelihood	-48.892		-48.382	

(Note) *, **, *** indicate significant at the 10% level, 5% level, 1% level, respectively.

As for factors of production, capital stock is mainly composed of oil extraction equipment and buildings. The positive and significant sign on the capital coefficient suggests that increasing firm's milling capacity and purchasing new equipment contributes to increase olive oil production. This result implies the modernisation process under PMN would upgrade the level of production. Likewise, we find a positive correlation between labour and extra virgin olive oil. Although the adoption of modern technology, such as continuous chains, is labour saving compared with the traditional method, labour is still a significant factor in increasing production.

The estimated coefficients of the technical inefficiency model are also as expected. The following four empirical results were found. First, the estimated coefficient of the employment of management staff for accounting, supplies or marketing (D_{MS}) is negative and statistically significant. This result indicates that the activities of management staff contribute to an increase in the level of technical efficiency. As mentioned, PMN allocated its budget for investments in employee training and capacity building through quality schemes and export promotion. This result implies that the accumulation of management knowledge, including marketing and quality control, would be a significant factor in upgrading efficiency. Second, the coefficient of the dummy variable of adoption of modern technology (D_{TEC}) is negative and statistically significant at the 1% level. This result confirms a positive effect of the adoption of modern technology on upgrading efficiency. According to the DGPA, the number of continuous chains increased from 163 (12% of total mills) in 1994 to 718 (41%) in 2010 with the implementation of PMN. This result implies that PMN, which promotes the introduction of modern technology such as continuous chains for oil extraction, contributed to improving efficiency. Third, the estimated coefficient of in-house production (*SOP*) is negative and statistically significant. This result suggests that an increase in the self-supply of olives contributes to an upgrade of the technical efficiency. The higher the internal production of olives, the greater is the stability of olive supplies from olive-growing farms as well as the production of standardized olive oil[6]. Lastly, the location dummy variable of the southern region (D_S) is positive and statistically significant. This indicates that the southern region of Tunisia showed a lower level of technical efficiency compared with the central region. According to the Olive Tree Institute in Tunisia, the level of capital investment and use of new extraction machineries in the southern region of Tunisia are lower compared with those in central and northern regions.

As explained in the estimation model, the variable *SOP*

[6] A stable supply of olives is one of bottlenecks to stabilize the production and export of olive oil. In Tunisia, levels of olive production fluctuate every year, as this sector is highly vulnerable to changes in annual precipitation. See Larbi and Chymes (2009).

was endogenised by the three instrumental variables, D_{TRD}, *SKL* and *SOS*. The estimated results of the auxiliary regression suggest that these instrumentals were positive and statistically significant. The positive sign of D_{TRD} suggests that firms that adopt the traditional method of oil extraction rely more on the self-supply of olives. This could be due to the daily trituration capacity of the traditional method which is lower compared to the modern method such as continuous chains. Since the modern method requires large quantities of olives, olive oil manufacturers cannot only rely on in-house production. By contrast, in the traditional method olives are ground into olive paste using large millstones. In this method, the introduction of water is minimal for malaxation of the paste, and the oil extraction is done at normal temperature (cold pressed). Compared with the modern method, these conditions are favourable for extracting high-quality olive oil without losing the aroma and taste, and they reduce the washing of polyphenols.

While the traditional method has such advantages in quality of extracted olive oil, it requires more manual labour and the extraction capacity is limited. In addition, this method calls for more waiting time for the olive oil to separate from the paste, resulting in a degradation of the product quality owing to exposure of the paste to oxygen and light. Olives are best harvested and the grinding process started within 24 hours, 72 hours at the longest, to produce high quality olive oil, since oxidation begins immediately after harvesting. However, in-house production of olives may mitigate these disadvantages by reducing the time from harvesting to pressing. In this sense, adoption of in-house production can be rational behaviour for olive oil producers using traditional methods.

Similarly, to avoid degradation of olive oil quality, firms try to collect olives from neighbouring olive-growing farms. The positive sign of the estimated parameter of *SOS* implies firms that prefer collecting olives from their neighbours tend to rely on the self-supply of olives. This behaviour is consistent with producing high-quality olive oil by minimizing the time from harvesting to pressing. Thus, it appears that quality-oriented firms may have an incentive to stabilize the supply of olives and save time after harvesting by collecting from their neighbours as well as producing them on their own farms.

The positive and significant parameter of *SKL* implies the accumulation of skilled labour is instrumental for in-house production. Generally, the traditional method requires skill for oil extraction compared with the modern method. Moreover, human skill is necessary to produce high-quality extra virgin olive oil, for instance, in the selection and separation of fresh olives and in the extraction of olives by cold press. Among firms that adopt in-house production, some quality-oriented firms introduced practices, such as selection of seeds by the cultivar and early harvesting of olives manually to avoid damaging the olives. These practices also require human skill.

The estimate of the variance parameter γ is positive and statistically significant at the 1% level, implying that inefficiency effects are significant in determining the level and variability of the olive oil producing firms. Thus, the stochastic frontier inefficiency model is empirically justified. Furthermore, two hypotheses related to the model parameters are examined using the likelihood test.[7] The value of the log-likelihood function under the specification of the alternative hypothesis (i.e. unrestricted model) is −29.828. The result of the first hypothesis of no inefficiency effects is rejected at the 1% level. In addition, we reject the null second hypothesis that no firm-specific factor makes a significant contribution to the explanation of the inefficiency effects[8].

Table 3 gives the estimations of firms' technical efficiency in distribution frequencies. The estimated efficiency scores indicate the existence of technical inefficiency in firms while more than half of the sample is relatively efficient with their efficiency scores more than 80.0%. The average level of technical efficiency is 72.9%, ranging from a minimum of 8.2% to a maximum 96.4%. It is suggested that firms in this sample are producing, on average, 72.9% of their potential at the current levels of technology and input. Seventy-five firms (66.4% of the total sample) are more efficient than the average. However, 16.8% of the sample firms show relatively inefficient levels with scores less than 40.0%. These results imply the possibility of these firms to increase their production by 27.1%, given the current state of technology and input levels.

Table 3 - *Frequency distribution of technical efficiency.*

Technical efficiency (%)	Number of firms	Percentage
0 < TE ≤ 20.0	5	4.4
20.0 < TE ≤ 40.0	14	12.4
40.0 < TE ≤ 60.0	6	5.3
60.0 < TE ≤ 72.9	13	11.5
72.9 < TE ≤ 80.0	14	12.4
80.0 < TE ≤ 100	61	54.0
Minimum efficiency	8.2	
Maximum efficiency	96.4	
Mean efficiency	72.9	
	(24.356)	

(Note) Standard deviations are in parentheses.
(Source) Results of the estimation of model corrected for endogeneity in Table 2.

[7] The null hypothesis can be tested using the generalized likelihood ratio statistic λ, given by $\lambda = -2\{L(H_0) - L(H_1)\}$. $L(H_0)$ and $L(H_1)$ denote the values of likelihood function under the null (H_0) and the alternative hypothesis (H_1), respectively. If the given null hypothesis is true, λ has approximately Chi-square distribution or mixed Chi-square distribution.

[8] The null hypothesis representing the empirical validity of translog specification over Cobb-Douglas form of production function was not rejected at 5% level of significance. While this result indicated indifference between the two specifications, we employed the translog specification for the sake of estimation purposes and its flexibility of the functional form.

Table 4 presents the comparison of the estimated efficiency scores by group (i.e. firms by location, firms employing modern technology in the olive oil-extraction process and those that use traditional methods, and firms that partially use olives produced in-house and those that use olives from outside). Accounting for the location effect, firms located in the central region have a relatively high efficiency score of 91.2%, whereas those in the south remain at 46.6%. This result is consistent with the estimation of the positive and significant value of the location dummy D_S in the inefficiency effects model (Table 2). These results indicate that the level of technical efficiency of firms located in the southern region is significantly lower than that of those in the central region. Relatively low standard deviation for the firms located in the central region suggests a level of efficiency close to the average (91.2%). However, in the southern region, the relatively high standard deviation indicates that the efficiency level is dispersed across firms. These results are consistent with the sign of regional dummies and observations by the Olive Tree Institute in Tunisia.

It is noteworthy that the average level of technical efficiency of the firms employing modern technology is estimated at 76.3% on average, whereas that of the firms employing traditional methods is 54.0%. The null hypothesis of no difference between the means of efficiency of these two groups was rejected at the 1% level by the *z*-test. This result confirms that the introduction of modern technology, such as continuous chains, increases the average level of efficiency. In addition, this empirical evidence implies that a governmental policy such as PMN contributed to an improvement of the extraction processes and capacities through the overhaul of equipment. Moreover, among the firms employing modern technology, the technical efficiency of firms using partially the olives produced in-house was estimated at 80.2%. Even in the firms employing the traditional method, in-house production of olives contributes to an efficiency improvement to 67.0% on average. Among the firms employing the traditional method, when we compare the average efficiency of firms using partially olives produced in-house and firms collecting olives from outside their firm, the *z*-test rejected the null hypothesis of no difference between these two groups at the 1% level. These results confirm the significance of self-supply of olives for improving efficiency. It also suggests that a combination of modern technology and in-house production of olives would contribute to achieving the maximum possible output. Indeed, more than half the firms (52.4%) located in the central region adopted this combination.

The average level of technical efficiency of the firms participated in PMN is 81.4% while those not participated is 72.1%. However, the *z*-test cannot reject the null hypothesis of no difference between the means of efficiency of these two groups. This is probably due to the low number of observations for the firms under PMN (9 observations). Although we cannot identify statistically significant positive effect of the participation of PMN on efficiency, at least we can confirm the pertinence of the direction of PMN that promotes the adoption of modern method for olive oil extraction.

Table 4 - *Frequency distribution of technical efficiency by group.*

Group	Number of firms	Technical efficiency (%)
Firms locate in northern region	34	77.6
		(15.362)
Firms locate in central region	43	91.2
		(2.139)
Firms locate in southern region	36	46.6
		(22.917)
Firms employ modern method	96	76.3
		(21.542)
Firms partially supply olives by in-house production	45	80.2
		(18.176)
Firms not supply olives by in-house production	51	72.8
		(23.758)
Firms employ traditional method	17	54.0
		(30.794)
Firms pratially supply olives by in-house production	7	67.0
		(28.131)
Firms not supply olives by in-house production	10	44.9
		(30.573)
Firms participated in PMN	9	81.4
		(21.725)
Firms not participated in PMN	104	72.1
		(24.525)

(Note) Standard deviations are in parentheses.
(Source) Results of the estimation of model corrected for endogeneity in Table 2.

6. Discussion

The reason why the introduction of the modern technology contributes to an efficiency upgrade may seem obvious. This extraction technology is continuous and automated, and it helps produce a large amount of good quality olive oil. Owing to its large daily production capacity, this method can avoid the need to stockpile olives and it is also efficient since each process of washing, crushing and extraction is continuous. Thanks to the centrifugation process of this method, yield performance is better as most of the olive oil is collected and well protected from contamination (Kiritsakis, 1998). By contrast, in the traditional method, the implicit knowledge and techniques for crushing, pressuring and separating, embedded in human skills, may differ among firms. Although operation of the continuous chains needs explicit knowledge for running automated machines such as crushing, malaxation, centrifugation and separation, the quality of output is standardized regardless of differences in implicit human skills. As a result, the modern method may help bridge differences in productivity and efficiency, barring random disturbances.

However, the level of technical efficiency varies among the firms employing modern technology. Table 4 showed the average level of efficiency of firms using partially olives produced in-house reached 80.2%, whereas that of firms using olives from outside their firms remained at 72.8%. This difference may be attributed to problems of olives supply and their quality. Artukoglu and Olgun (2008) suggest that there are significant factors at play that affect the quality of olive oil, such as the method used to transport olives to the production units and the waiting period before processing. Olives are best transported in plastic boxes, yet olive farms in Tunisia mostly use sacks for transportation. Owing to the oxidation/fermentation process, the acidity of the oil extracted from olives stored in sacks and kept for long periods before being processed increases significantly and reduces its quality. Although some firms in Tunisia separate and store olives in plastic containers by region, farms or even cultivar, usually olives brought from various olive farms are mixed.

These facts imply the time from harvesting to processing and degree of oxidation i.e., freshness of olives as raw materials is a significant factor in the production of high-quality olive oil. However, freshness may be difficult to observe and control. Once olives collected from outside the firms are mixed, it becomes more difficult to monitor and trace their freshness. Thus, it can be said that information asymmetry on quality of raw materials (olives) exists between olive-oil extraction firms and olive farms, and between the firms and middlemen. In addition, transaction costs may emerge for collecting olives of standard quality. However, in-house production may reduce transaction costs and mitigate such variations in the quality of olives. Indeed, some firms in Tunisia adopt early-harvesting practices by hand to prevent damage to the olives and select good olives to control the degree of freshness. In addition, in-house production of olives can alleviate risks resulting from instability of olive yields due to fluctuating rainfall. Olive oil producers who have direct control on the supply of olives through inhouse production would be able to guarantee both good quality and a stable supply of olive oil.

Despite the advantages of self-supply of olives for the production of high quality oil, it should be noted that the firms with in-house production constituted only 39.8% of the sample. This fact suggests that the adoption of in-house production is not a major phenomenon. Yet, an explanation may be possible from the demand side and process of industrial development. It is generally observed that the production of low-quality products targeting the domestic market is a major pattern in the early phase of industrial development. At this phase, producers strive to produce simple and standardized products rather than high-quality differentiated products (Sonobe and Otsuka, 2006). In Tunisia, the domestic consumer is the main target of the olive oil market. Indeed, access to the export market is also limited as only seven firms out of the 113 samples (6.2%) export olive oil, and the majority of olive oil is exported in bulk. As long as domestic consumers dominate the market and exports are in bulk, the pressure of quality assurance may not be much for olive oil producers. In such a situation, incentives for the introduction of in-house production to control product quality and to meet quality assurance standards may be low. Indeed, among Tunisian olive oil producers, only 28 firms of the survey sample introduced quality control measures (24.8%).

In such a phase, i.e. the quantity expansion phase of industrial development, demand for standardized olive oil products dominates the domestic market[9]. Owing to its large production capacity and automated system, continuous chains are suited to the production of standardized olive oil. According to Kapellakis *et al.* (2008), a factor that affects the oil yield is the amount of water added to the olive paste. Actually, in the malaxation process of the continuous chains, heated water is added to keep the paste around 27°C, allowing the smaller droplets of oil to be released more easily, since a temperature increase results in lower viscosity of the oil and more olive oil. Moreover, the centrifugation process of this method has the advantage of better yield performance, as most of the oil is collected (Kiritsakis, 1998). As evident from the higher efficiency score of the firms employing modern technology (76.3%), the continuous chain may be productive in terms of producing standardized olive oil.

On the contrary, at a more advanced phase, i.e. quality improvement, it becomes increasingly important to upgrade the quality of products and increase the agility of responding to increasing and changing demands, as poor quality products become increasingly difficult to sell (Schmitz and Nadvi, 1999; Sonobe *et al*., 2004; Sonobe and Otsuka, 2006). At this phase, demand for high-quality differentiated products increases. As noted, the continuous chains are productive and suited to mass production; however, some firms prefer traditional methods such as cold-pressed without heating, and try to establish a brand of the cold-pressed oil. From the viewpoint of nutritional composition, the centrifugal process of the modern method has a disadvantage in terms of quality of oil, since a significant amount of phenols (natural anti-oxidants) are lost by using water and energy for heating (Kiritsakis, 1998). The taste and flavour may also suffer degradation in the heating-up process.

Regarding the product differentiation, experience of Jaén's mountain olive grove regions in Spain suggested that the advantage of the spatial concentration of a wide-spread network of olive firms, oil mills and marketing firms, input suppliers, companies using olive by-products and local institutions related to olive oil and rural development. Development of such local olive oil systems, spatial differentiation and segmentation in mountainous in different geographical areas may contribute to produce specific olive oils and add value to local chains, realizing by the development of Protected Designations of Origin (POD) labelled oils (Sanz-Cañada *et al.*, 2015). In Spanish olive oil production, Sanz-Cañada and Macías-Vázquez (2005) suggested the significance of the POD for certifying quality, geographical origin and environmental attributes of

[9] Based on the case studies in developing countries, Sonobe and Otsuka (2006) found that the quantity expansion phase is followed by the quality improvement phase in the process of industrial development.

the products they give their distinctive label. In Tunisia, some olive oil factories developed a link and contract with olive-growing farmers to stabilize the supply of high-quality olives and develop local supply chains. Also, some export-oriented olive oil factories extract olive oil without mixing cultivars and produce labelled oil by cultivar. These facts suggest that the development of local supply chains is crucial to produce differentiated product and establish local brands.

As far as improvement in the quality is concerned, in-house production may become increasingly important to differentiate olive oil products in terms of quality. For instance, early harvesting and harvesting by hand (hand-picked) observed in some firms that have adopted in-house production are possible ways of establishing a brand. Production of olive oil by cultivar is another way to add value. Generally, the improvement of product quality entails the use of high-quality inputs. While the establishment of long-term relationships with dependable and competent suppliers is a way to secure high-quality inputs for the improvement of product quality, another way is to establish a vertically integrated production system in which such inputs are produced in-house (Sonobe and Otsuka, 2011). In-house production of olives may contribute to the development of such differentiated products[10].

7. Conclusion

This paper is the first attempt to investigate firm-level technical efficiency of olive oil producers in Tunisia during the implementation of PMN. Our empirical findings indicate that production of olive oil in Tunisia is a stochastic phenomenon. The estimated efficiency scores imply olive oil producing units in Tunisia can further increase their production by 27.1% through a more efficient use of technology and production inputs. Interestingly, introduction of modern technology, employment of management staff, and in-house production of olives contribute to improving the technical efficiency. The average technical efficiency of firms adopting modern technology such as continuous chains in the oil-extraction process is higher than that of firms employing the traditional method. Introduction of in-house production of olives is also a significant factor for the improvement of efficiency. These results also suggest that a combination of modern technology and in-house production of olives would help achieve the maximum possible output.

The introduction of modern extraction technologies contributes to an efficiency upgrade because of its continuous and automated system. On the other hand, adoption of in-house production can be deemed rational behaviour because it minimizes the time taken from harvesting to pressing. In-house production helps mitigate variations in the quality of olives, since information asymmetry on quality may exist between olive oil extraction units and olive farms and between the firms and middlemen. In addition, it may also contribute to alleviating risks resulting from the instability of olive yields.

Despite its several advantages, the adoption of in-house production is not a major phenomenon. The underdevelopment of in-house production can be explained from the demand side and the phase of industrial development. As long as domestic consumers dominate the market and exports are done in bulk, the pressure of quality assurance is not so great for oil producers, resulting in low incentives to develop internal production. In such a quantity expansion phase, demand for standardized products dominates the domestic market. While we cannot find a statistically significant effect of the participation of PMN on upgrading technical efficiency, the implementation of PMN which promotes the introduction of continuous chains is in the right direction, as it is suited to mass production.

On the contrary, demand for differentiated products increases in the quality improvement phase. Indeed, some quality-oriented firms in Tunisia prefer the traditional method such as cold-pressed without heating and early harvesting by hand. They also try to establish a brand of value-added olive oil. From quality and nutritional viewpoints, the modern method has a disadvantage because considerable amount of phenols are lost during the centrifugal process, and taste and flavour may suffer degradation in the heating process. This paper finds that in-house production becomes increasingly important to develop differentiated olive oil products in terms of quality. In this context of Tunisian olive oil production, higher efficiency of internal production implies significant vertical integration, from the cultivation of olives to the extraction of olive oil.

As policy implications, this paper emphasise the significance of the adoption of modern method and accumulation of management knowledge for upgrading productivity of olive oil manufactures. The participation to PMN that encourages the adoption of modern method of olive oil extraction should be more promoted. However, for reducing variations in quality of extracted oil and help stabilizing fluctuations of its supply, the merit of the in-house production and promotion of the vertical integration should be underlined which would minimize the time from harvesting to processing.

Based on these implications, this paper recommends two development strategies for olive oil manufactures. One has the objective of maximizing the volume of production of olive oil, extra virgin olive oil in particular, by introducing modern extraction method such as continuous chains. This strategy is significant in quantity expansion phase to maximize the production of standardized products. The second strategy is focused on producing high-quality, dif-

[10] R&D activities are limited but somewhat observed in Tunisian olive oil firms. From the survey, we find out that the number of firms owning laboratory for the analysis of olive oil was 18 (15.9%), and that of firms using computer and internet for production and marketing was 23 (20.4%).

ferentiated olive oil, using traditional methods such as cold-press. The product differentiation is getting more crucial in the quality improvement phase. For both strategies, the stable supply of olives with high quality is essential. To sustain its stable supply, this paper recommends developing a link and contract with olive-growing farms for assuring quality of olives in the short run; however, in the long run, the introduction and expansion of in-house production of olives should be promoted towards the development of vertical integrated production system.

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References

Aigner D.J., Lovell C.A.K. and Schmidt P., 1977. Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 6: 21-37.

Angulo A.M., Mtimet N., Dhehibi B., Atwi M., Ben Youssef O., Gil J.M. and Sai M.B., 2011. A revisited gravity equation in trade flow analysis: An application to the case of Tunisian olive oil exports. *Investigaciones Regionales*, 21: 225-239.

Artukoglu M.M. and Olgum A., 2008. Quality problems in raw material of olive oil mills and marketing channels: case of Turkey. *Agricultura Tropica Subtropica*, 41(3): 128-131.

Battese G.E. and Coelli T.J., 1993. *Stochastic frontier production function incorporating a model for technical inefficiency effects*. Department of Econometrics, University of New England, Armidale, Australia. Working Paper in Econometrics and Applied Statistics, 69.

Battese G.E. and Coelli T.J., 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, 20(2): 325-332.

Charnes A., Cooper W.W. and Rhodes E., 1978. Measuring efficiency of decision making units. *European Journal of Operational Research*, 2: 429-444.

Coelli T.J., 1996. A Guide to FRONTIER *Version 4.1: A computer program for stochastic frontier production and cost function estimation*. Centre for Efficiency and Productivity Analysis. Department of Econometrics, University of New England, Armidale, Australia. CEPA Working Papers, 7/96.

Damas R.E. and Romero L.C., 1997. Análisis no paramétrico de la eficiencia relativa de las Almazaras cooperativas en la provincia de Jaén Durante el período 1975-1993. *Economía Agraria*, 180: 279-304.

Davidson R. and MacKinnon J., 1993. *Estimation and inference in econometrics*. New York and Oxford: Oxford University Press.

Dios-Palomares R. and Martínez-Paz J.M., 2011. Technical, quality and environmental efficiency of the olive oil Industry. *Food Policy*, 36: 526-534.

Farrell M.J., 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society*, Series A, 120: 253-90.

Greene W.H., 1980. Maximum likelihood estimation of econometric frontier functions. *Journal of Econometrics*, 13: 27-56.

Huang C.J. and Liu J.T., 1994. Estimation of a non-neutral stochastic frontier production function. *Journal of Productivity Analysis*, 2: 171-180.

Jondrow J., Lovell C.A.K., Materov I.S. and Schmidt P., 1982. On the estimation of technical inefficiency in stochastic frontier production function model. *Journal of Econometrics*, 19: 233-238.

Kapellakis E., Tsagarakis K.P. and Crowther J.C., 2008. Olive oil history, production and by-product management. *Reviews in Environmental Science and Biotechnology*, 7: 1-26.

Karray B. and Kanoun F., 2013. Forces, faiblesses, opportunités et menaces de la filière oléicole en Tunisie. *New Medit,* 12(4): 35-45.

Kiritsakis P., 1998. *Olive oil, from the tree to table*. 2nd ed. Wiley-Blackwell.

Kumbhakar S.C., Ghosh S. and McGuckin J.T., 1991. A generalized production frontier approach for estimating determinants of inefficiency in U.S. dairy farms. *Journal of Business and Economic Statistics*, 9: 279-286.

Lachaal L., Karray B., Dhehibi B. and Chebil A., 2005. Technical efficiency measures and its determinants for olive producing farms in Tunisia: a Stochastic Frontier Analysis. *African Development Review*, 17(3): 580-591.

Larbi W. and Chymes A., 2009. The impact of the government policies and incentives to promote the export of agricultural products in Tunisia: case of olive oil. In: *113th Seminar of the European Association of Agricultural Economists (EAAE)*: 1-30.

Lovell C.A.K., 1993. Production frontiers and productive efficiency. In: Fried H.O., Lovell C.A.K. and Schmidt S.S. (eds). *The measurement of productive efficiency: Techniques and applications*, New York: Oxford University Press, 3-67.

Meeusen W. and van den Broeck J., 1977. Efficiency estimation from Cobb-Douglas production function with composed error. *International Economic Review*, 18: 435-444.

Mili S., 2006. Olive oil marketing on non-traditional markets: prospects and strategies. *New Medit*, 5(1): 27-37.

Tzouvelekas V., Giannakas K., Midmore P. and Mattas K., 1999. Decomposition of olive oil production growth into productivity and size effects: a frontier production function approach. *Cahiers d'économie et Sociologie Rurales*, 51: 5-21.

Tzouvelekas V., Pantzios C.J. and Fotopoulos C., 2001.

Technical efficiency of alternative farming systems: the case of Greek organic and conventional olive-growing farms. *Food Policy*, 26: 549-569.

Reifschneider D. and Stevenson R., 1991. Systematic departures from the frontier: a framework for the analysis of firm inefficiency. *International Economic Review*, 32: 715-723.

Richmond J., 1974. Estimating the efficiency of production. *International Economic Review*, 15: 515-521.

Saldias R. and von Cramon-Taubadel, 2012. *Stephan access to credit and the determinants of technical inefficiency among specialized small farmers in Chile*. Göttingen: Universität Göttingen. Diskussionspapiere, Department für Agrarökonomie und Rurale Entwicklung, 1211.

Sanz-Cañada J., García-Brenes M.D. and Barneo-Alcántara M., 2015. Value chain and typicity analysis in Jaén Mountain olive oil, Spain. *New Medit*, 14(3): 50-60.

Sanz-Cañada J. and Macías-Vázquez A., 2005. Quality certification, institutions and innovation in local agro-food systems: protected designations of origin of olive oil in Spain. *Journal of Rural Studies*, 21(4): 475-486.

Schmitz H. and Nadvi K., 1999. Clustering and industrialization: Introduction. *World Development*, 27(9): 1503-1514.

Sonobe T., Hu D. and Otsuka K., 2004. From inferior to superior products: An inquiry into the Wenzhou model of industrial development. *Journal of Comparative Economics*, 32(3): 542-563.

Sonobe T. and Otsuka K., 2006. *Cluster-based industrial development: An East Asian model*. Hampshire, UK: Palgrave Macmillan.

Sonobe T. and Otsuka K., 2011. *Cluster-based industrial development: A comparative study of Asia and Africa*. Hampshire, UK: Palgrave Macmillan.

Wooldridge J.M., 2002. *Econometric analysis of cross section and panel data*. Cambridge, Massachusetts, London: MIT Press.

World Bank, 2009. *Tunisia's global integration: A second generation of reforms to boost growth and employment*. Washington D.C.: The World Bank.

Zaibet L., 2007. La qualité des produits agricoles et agroalimentaires en Tunisie: la construction d'une stratégie. In: *Mediterra 2007, Identité et Qualité des Produits Alimentaires Méditerranéens*. Paris: Presses de Sciences Po: 199-217.