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# Technical Efficiency of Sea Bass and Sea Bream Production of European Aquaculture Firms

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## INTRODUCTION

- In the decade (2005-2014), European producers of farmed sea bass and sea bream in the Mediterranean Sea have had to compete strongly among them as well as with Turkish producers to be competitive (Globefish, 2015).
- One important factor of economic competitiveness is to be productive or technical efficient. Efficiency studies on aquaculture are relatively few compared with other industries and they are focused mainly on no European countries (Alam, 2011). Moreover, the identification of the factors that determine aquaculture firms' productivity is also an important issue to propose managerial decisions in the sector.
- The purpose of this work is twofold:
  - First, we have evaluated the technical efficiency of the European cultured sea bass and sea bream producers in the Mediterranean Sea from 2005 to 2014.
  - Second, we have analyzed the effect of some factors such as location, type of production (organic and non-organic), years of experience, and size on firms' productivity.

## The sea bass and sea bream production in Europe

- Sea bass and sea bream have become two of the main products of the European aquaculture being two of the most important cultured fish species economically along the Mediterranean coast.
- The EU is one of the largest producers of sea bass and sea bream in the world, being Greece the largest producer within the EU followed by Spain. Both species represent respectively 9.88% and 10.83% of the total value of the European aquaculture sector (EU, 2018).
- However, the Turkish sea bass and sea bream industry has been steadily increasing production volumes for the last decade to the point where Turkey is now the world's major producer of sea bass, competing with European producers with lower prices (Globefish, 2015).

# TE definition and measurement

- Technical efficiency (TE) refers to the ability of a decision-making unit (farm or firm) to minimize input used in the production of a given bundle of outputs, or the ability to obtain maximum output from a given bundle of inputs (Farrell, 1957; Kumbhakar and Lovell, 2000; Alam, 2011).

- The measurement of TE is based upon deviations of observed output from the best production or efficient production frontier. The frontier production function defines potential output that can be produced by a firm with the given level of inputs and technology (Kumar et al., 2004). If a firm's actual production point lies on the frontier it is perfectly efficient whereas if it lies below the frontier then it is technically inefficient, being the ratio of actual to potential production the level of efficiency.

- Two methodologies are commonly used to describe the efficient production frontier and, therefore, estimate efficiency scores (Tingley et al., 2005): the stochastic production frontier (SPF) and the data envelopment analysis (DEA). Both approaches have been widely used to analyze this topic applied to the aquaculture sector (Bozoglu et al., 2006; Cinemre et al., 2006; Kaliba and Engle, 2006; Alam and Jahan, 2008; Alam, 2011; Islam et al., 2016; Ngoc et al., 2018).

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# The stochastic production function (SPF)

According to Battesse and Coelli (1995), a general SPF model for panel data can be given by:

$$LnY_{it} = Ln(\mathbf{x}_{it}, \boldsymbol{\beta}) + v_{it} - u_{it}$$

were $Y_{it}$ denotes the production of the $i$-th firm at the $t$-th time period; $\mathbf{x}_{it}$ is a vector of input quantities and **b** is a vector of unknown parameters to be estimated. Finally, $u_{it}$ is a time-varying panel-level effect to estimate the technical inefficiency of firm $i$ at year $t$ (where $u_{it} \geq 0$) and $v_{it}$ is assumed to be an independent and identically distributed $N(0, \sigma_v^2)$ random error.
There are several potential function forms for the SPF, being the logarithmic transcendental (translog) and Cobb-Douglas production functions the most common. A translog function is given by:

$$LnY_{it} = \beta_0 + \sum_j \beta_j \, LnX_{it,j} + \frac{1}{2}\sum_j \sum_k \beta_{j,k} LnX_{it,j} \, LnX_{it,k} + v_{it} - u_{it}$$

On the other hand, the Cobb–Douglas function is a special case of the translog production function where all $\beta_{j,k} = 0$. In this case we would have the following model:

$$LnY_{it} = \beta_0 + \sum_j \beta_j \, LnX_{it,j} + v_{it} - u_{it}$$

- We have used an unbalanced panel composed of a sample of 30 European production firms of cultured sea bass and sea bream in the Mediterranean Sea.
- The period of time analyzed ranges from 2005 to 2014 (10 years). Economic data for this analysis was obtained from the AMADEUS and EUMOFA databases.
- To estimate technical efficiency, we have adopted the Battese and Coelli's (1993) SPF model using translog and Cobb-Douglas production functions for panel data.

$$LnY_{it} = \beta_0 + \beta_1 Ln(LAB_{it}) + \beta_2 Ln(CAP_{it}) + \beta_3 Ln(EXP_{it}) + v_{it} - u_{it}$$

- Simultaneously, the technical inefficiency values estimated with the specified SFP model are regressed using different specific-firm factors.

$$u_{it} = \delta_0 + \delta_1(TIME_t) + \delta_2(WEST_i) + \delta_3(EAST_i) + \delta_4(ORG_i) + \delta_5(AGE_{it}) + \delta_6(SIZE_{it}) + \varepsilon_{it}$$

- Maximum likelihood (ML) estimates of the parameters of the stochastic frontier and the inefficiency effects models were obtained simultaneously using FRONTIER 4.1.

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# Sample representativeness

| Country | Number of firms | | | Number of employees | | |
|---|---|---|---|---|---|---|
| | Population | Sample | % | Population | Sample | % |
| Croatia | 5 | 4 | 80.0 | 374 | 327 | 87.4 |
| Cyprus | 4 | 2 | 50.0 | 171 | 149 | 87.1 |
| France | 7 | 2 | 28.6 | 191 | 50 | 26.2 |
| Greece | 36 | 7 | 19.4 | 3,971 | 3,025 | 76.2 |
| Italy | 18 | 10 | 55.6 | 339 | 232 | 68.4 |
| Slovenia | 2 | 1 | 50.0 | 11 | 8 | 72.7 |
| Spain | 28 | 4 | 14.3 | 951 | 212 | 66.6 |
| All countries | **100** | **30** | **30.0** | **6,008** | **4,003** | **66.6** |

*Source*: authors' elaboration using AMADEUS database with data of the year 2014.

# Descriptive statistics (period 2005-2014)

| Variable | N | Mean | SD | Min. | Max. |
|---|---|---|---|---|---|
| *Y* = Cultured sea bass and sea bream production (tons) | 189 | 4,655.42 | 9,649.19 | 3.57 | 43,806.33 |
| *LAB* = Labor (number of employees) | 189 | 141.90 | 304.74 | 1 | 1,843 |
| *CAP* = Total assets (mill. USD) | 189 | 59.35 | 135.98 | 0.08 | 530 |
| *EXP* = Expenditure in fish feed and other supplies (mill. USD) | 189 | 24.51 | 52.63 | 0.04 | 234 |
| *TIME* = Linear trend (year) | 189 | 6.47 | 2.62 | 1 | 10 |
| *WEST* = Location dummy (West Mediterranean Sea) | 189 | 0.20 | 0.40 | 0 | 1 |
| *EAST* = Location dummy (East Mediterranean Sea) | 189 | 0.33 | 0.47 | 0 | 1 |
| *ORG* = Production type dummy (organic production) | 189 | 0.56 | 0.50 | 0 | 1 |
| *AGE* = Firm's experience (years) | 189 | 17.24 | 8.54 | 0 | 38 |
| *SIZE* = Firm's size (revenues, mill. USD) | 189 | 29.95 | 58.80 | 0.02 | 272.13 |

*Source*: authors' elaboration using AMADEUS and EUMOFA databases.

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# ML estimates of the SPF model

| Variable | Parameter | Cobb-Douglas production function | | Translog production function | |
|---|---|---|---|---|---|
| | | *Coefficient* | *t-ratio* | *Coefficient* | *t-ratio* |
| Constant | $\beta_0$ | 5.20 | 96.75*** | 5.31 | 41.30*** |
| Ln (*LAB*) | $\beta_1$ | 0.12 | 5.09*** | 0.18 | 2.05** |
| Ln (*CAP*) | $\beta_2$ | 0.17 | 6.41*** | 0.01 | 0.13 |
| Ln (*EXP*) | $\beta_3$ | 0.68 | 30.89*** | 0.79 | 10.58*** |
| Ln $(LAB)^2$ | $\beta_4$ | | | –0.08 | 1.99** |
| Ln $(CAP)^2$ | $\beta_5$ | | | –0.30 | 3.81*** |
| Ln $(EXP)^2$ | $\beta_6$ | | | –0.11 | 2.80*** |
| Ln (*LAB*) x Ln (*CAP*) | $\beta_7$ | | | 0.17 | 3.43*** |
| Ln (*LAB*) x Ln (*EXP*) | $\beta_8$ | | | –0.12 | 3.96*** |
| Ln (*CAP*) x Ln (*EXP*) | $\beta_9$ | | | 0.19 | 3.80*** |
| Sigma squared | $\sigma^2$ | 0.71 | 5.26*** | 0.46 | 6.69*** |
| Gamma | $\gamma$ | 0.98 | 150.31*** | 0.97 | 122.35*** |
| Log-likelihood | | 12.39 | | 23.50 | |
| Likelihood ratio test | | 160.98*** | | 178.75*** | |
| Test LR: all $b_{j,k} = 0$ | | 22.23*** | | | |

***Significance at the 1% level. **Significance at the 5% level.

# ML estimates of the inefficient effects model

| Variable | Parameter | Cobb-Douglas production function | | Translog production function | |
|---|---|---|---|---|---|
| | | *Coefficient* | *t-ratio* | *Coefficient* | *t-ratio* |
| Constant | $\delta_0$ | –2.55 | 2.76*** | –0.89 | 2.11** |
| *TIME* | $\delta_1$ | 0.29 | 3.12*** | 0.15 | 3.47*** |
| *WEST* | $\delta_2$ | 0.24 | 0.67 | 0.30 | 1.16 |
| *EAST* | $\delta_3$ | –2.01 | 2.15** | –1.85 | 3.01*** |
| *ORG* | $\delta_4$ | –0.53 | 2.08** | –0.34 | 1.62 |
| *AGE* | $\delta_5$ | –0.09 | 4.35*** | –0.06 | 4.82*** |
| *SIZE* | $\delta_6$ | –0.00 | 0.32 | –0.01 | 1.70* |

***Significance at the 1% level. **Significance at the 5% level. *Significance at the 10% level.

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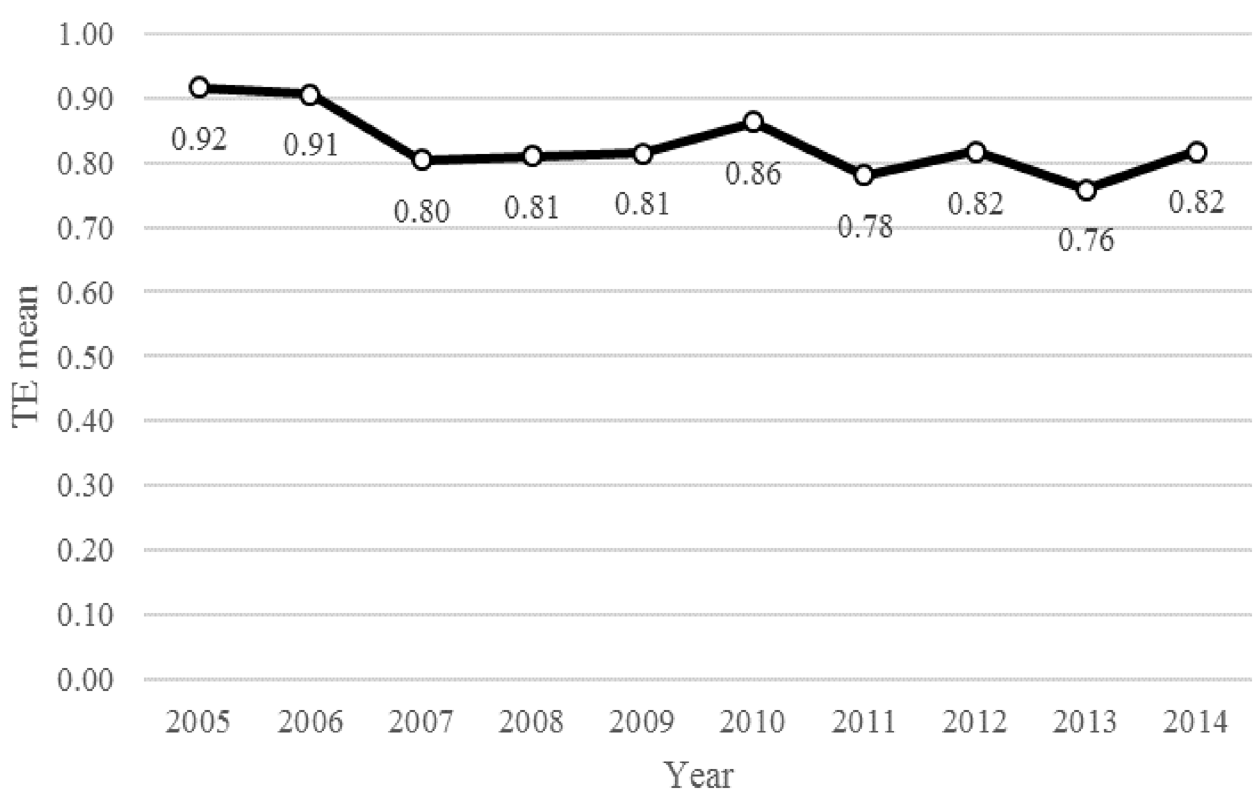
## RESULTS

### Yearly evolution of average TE scores (translog SPF)



## Distribution of firms' average TE scores in deciles range (translog SPF)

| TE score | Frequency | % | Cumulative % |
|---|---|---|---|
| **0.00 – 0.50** | 1 | 3.3 | 3.3 |
| **0.51 – 0.60** | 2 | 6.7 | 10.0 |
| **0.61 – 0.70** | 3 | 10.0 | 20.0 |
| **0.71 – 0.80** | 8 | 26.7 | 46.7 |
| **0.81 – 0.90** | 8 | 26.7 | 73.3 |
| **0.91 – 1.00** | 8 | 26.7 | 100.0 |
| **Total** | **30** | **100.0** | **-** |

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## Distribution of firms' TE scores and mean values of explicative variables by country (period 2005-2014)

| Country | Range of technical efficiency by country (translog SPF) | | | | Explicative variables of technical inefficiency by country (mean values) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Mean* | *Min.* | *Max.* | *Range* | *WEST (dummy)* | *EAST (dummy)* | *ORG (dummy)* | *AGE (years)* | *SIZE (mill. USD)* |
| **Croatia** | 0.68 | 0.52 | 0.84 | 0.32 | 0 | 0 | 0.28 | 10.61 | 6.35 |
| **Cyprus** | 0.89 | 0.89 | 0.90 | 0.01 | 0 | 1 | 0.45 | 18.82 | 14.26 |
| **France** | 0.81 | 0.73 | 0.89 | 0.16 | 1 | 0 | 1.00 | 21.75 | 5.82 |
| **Greece** | 0.92 | 0.90 | 0.95 | 0.05 | 0 | 1 | 1.00 | 20.94 | 87.38 |
| **Italy** | 0.74 | 0.50 | 0.92 | 0.42 | 0 | 0 | 0.20 | 17.86 | 7.63 |
| **Slovenia** | 0.70 | 0.70 | 0.70 | 0.00 | 0 | 0 | 1.00 | 4.50 | 1.37 |
| **Spain** | 0.80 | 0.74 | 0.88 | 0.15 | 1 | 0 | 0.44 | 14.08 | 14.53 |
| **All countries** | **0.79** | **0.50** | **0.95** | **0.45** | **0.20** | **0.33** | **0.56** | **17.24** | **29.95** |

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## CONCLUSIONS

- According to the results obtained with the Cobb-Douglas production function, the firms used in our analysis were operating at decreasing returns to scale. The variable of feed and other supplies expenditures (*EXP*) was the input factor with the highest elasticity.
- We can conclude that the average level of productivity of European firms producing cultured sea bass and sea bream was very high in the period 2005-2014 with a mean value of 0.79. However, we have also observed that the TE mean presents a very smooth decreasing linear trend.
- On the other hand, the results show a wide variation in the average of the estimated technical efficiencies among the European countries, ranging between 0.50 and 0.95, what shows a wide room for improvement in the technical efficiency of some countries (mainly for Italian and Croatian firms).
- On average, Greek and Cypriot firms seem to be the most productive with a TE mean of 0.92 and 0.89 respectively, whereas the Croatian and Slovenian firms seem to be the least productive with a TE mean of 0.68 and 0.70 respectively.
- We have found strong evidence that technical efficiency of those firms that are farming sea bass and sea bream in the Mediterranean Sea is positively related to their location (better environmental conditions in the East Mediterranean Sea) and their years of experience (more knowledge). On the other hand, firms' size has also a positive effect although it is not so significant. Thus, the short experience and small size seem to be the two factors that are impacting negatively in the productivity of Croatian and Slovenian firms, whereas that the location in the East of the Mediterranean Sea, the more years of experience, and the larger size are factors that are impacting positively in the productivity of Greek and Cypriot firms.

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