ECONOMIC DISCUSSION PAPERS

Efficiency Series Paper 02/2001

Some Issues on the Estimation of Technical Efficiency in Fisheries

Antonio Álvarez

Departamento de Economía

Universidad de Oviedo

UNIVERSIDAD DE OVIEDO

DEPARTAMENTO DE ECONOMÍA

PERMANENT SEMINAR ON EFFICIENCY AND PRODUCTIVITY

SOME ISSUES IN THE ESTIMATION OF TECHNICAL EFFICIENCY IN A FISHERY[§]

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Abstract

Although the study of productive efficiency has not been a traditional field of research in fishery economics, some recent papers have started to deal with this important topic. However, the estimation of technical efficiency in this sector has to take into account some factors which stem from the fact that fishing is different from other productive activities in several aspects. In this paper we study the implications of multiple species, how to deal with unmeasured biomass stock, the importance of trip length and the choice of fishing ground.

Key words: technical efficiency, stochastic frontiers, fisheries.

[♣] The author thanks many valuable comments by M. Arellano, C. Arias, J. Millán, C. Morrison Paul, L. Orea, J. Rodríguez-Poo and D. Roibás.

[*] Department of Economics, University of Oviedo, Spain. E-mail: aalvarez@econo.uniovi.es

1. Introduction

The important decline in fish stocks over the last century has prompted governments to regulate the fisheries in order to stop overfishing. Several policy measures, such as input restrictions, fleet reduction programs and fishing quotas have been implemented in order to reduce fishing effort. The efficacy of these policies may be hindered by two factors: the existence of technical inefficiency and excess capacity. In this paper I will concentrate on the study of efficiency in fisheries. [1]

Although the study of productive efficiency has not been a traditional field of research in fishery economics, some recent papers have started to deal with this important topic (Salvanes and Steen, 1994; Kirkley *et al.*, 1995, 1998; Campbell and Hand, 1998; Squires and Kirkley, 1999; Grafton *et al.*, 2000; Pascoe *et al*., 2001).

However, the estimation of technical efficiency in this sector has to take into account some factors which stem from the fact that fishing is different from other productive activities in several aspects. The most important are:

- Multiple-Species output: Even though fishers usually target a particular species, most of the times they end up capturing other types of fish. This fact opens up some alternatives to model a multiproduct technology.

- Biomass stock: Since output (catch) depends on the stock size of fish, some papers try to include it in the production function. Given that this information is not readily available in many cases, researches end up using stock proxies. This raises some interesting modeling issues.

- Trip length: The time dimension of data is important. In many situations boats return to port on the very same say, while some other times fishing-trips last much longer. Therefore, trip length must be introduced as a control variable.

- Fishing ground: In each trip, fishers have to choose a particular fishing ground. This aspect implies that there are two possible ways to measure technical efficiency: conditional or unconditional on the location choice.

[1] For an up-to-date overview on capacity utilization measurement in fisheries see Paul (2000).

These particular characteristics of the fishing activity have interesting modeling and estimation implications. In this paper we discuss these issues within the framework of the parametric approach to efficiency analysis.

The paper is organized as follows. Section 2 reviews the literature on technical efficiency and the empirical work on fishing efficiency. Section 3 discusses in depth the modeling and estimation issues. Section 4 contains some conclusions.

2. Technical efficiency in fisheries

The literature on the measurement of productive efficiency starts with the seminal paper of Farrell (1957). However, only very recently have researchers paid attention to the study of fishing efficiency in the tradition of Farrell. The first paper to use this type of analysis is Hannesson (1983), who estimated a deterministic production frontier for the cod and saithe fishery in Norway. The next wave of papers use the notion of stochastic frontiers introduced by Aigner, Lovell and Schmidt (1977), which allows for the separation of pure random events (such as luck) from inefficiency. The stochastic frontier function can be written as:

$$y_i = f(x_i) + v_i - u_i \qquad (1)$$

where y_i is the output of boat i and x_i the vector of inputs. The error term is composed of two terms: a one sided error term (u_i) that represents technical inefficiency and a symmetric error term (v_i) that is independent and identically distributed with zero mean and constant variance (σ_v^2).

The term v accounts, among other things, for luck. Several papers have studied which is more important in explaining differences in catches among vessels, efficiency or luck. They usually find that efficiency explains a higher proportion of the total variance than luck, although the opposite result can be found in Alvarez, Perez and Schmidt (2001).

Equation (1) can be estimated by maximum likelihood after assuming some distribution for the two error components. The usual assumption for v_i is that it is normally distributed, while for u_i the most common distributions are half-normal and truncated normal. Grafton *et al*. (2000) estimate this model using data of the halibut fishery in Canada.

In fisheries it is not very common to work with cross-section data since in most cases information on different trips for the same boat is available. The panel data production frontier can be written as:

$$y_{it} = \alpha + x_{it}\beta + v_{it} - u_{it} \qquad (2)$$

where subscript t stands for time.

This model implies that TE is time variant. Equation (2) was first estimated by Pitt and Lee (1981). They comment: "Estimation of this model is the same as set forth in Aigner et al. (1977) for a single cross-section and the benefits of pooled data are minimal". In the fisheries literature, Kirkley *et al.* (1995) estimate the equivalent to this model by maximum likelihood with panel data on vessels of the sea scallop fishery.

A refinement of the model in equation (2) is the well known Battese and Coelli (1995) one-stage model, which allows to model the inefficiency effects. Kirkley *et al.* (1998), Eggert (2000), Coglan and Pascoe (2001), among others, have applied this model to fisheries.

One problem with the Pitt and Lee and the Battese and Coelli models is that they do not consider the panel nature of the data. That is, they estimate what it is known sometimes as a pooled model since they do not take into account that the same firms are observed in different periods. Therefore, they do not use panel data to control for unobservable heterogeneity.

Schmidt and Sickles (1984) analyze the estimation of production frontiers with panel data.[2] In order to do that, some structure has to be assumed on the inefficiency term. If TE is assumed to be time invariant, then $u_{it}=u_i$. In this case, if the individual effects (u_i) are uncorrelated with the regressors, two estimation alternatives exist. One is to use the generalized least squares estimator of the traditional random effects model (Balestra and Nerlove, 1966) to estimate α and β consistently. In fisheries only two papers have used this estimation technique: Squires and Kirkley (1999) and Alvarez and Perez (2000). The other alternative consists in making distributional assumptions for u_i and v_{it} and estimate the model by maximum likelihood. This estimation technique has been applied in fisheries

[2] This approach overcomes an important problem of stochastic frontier estimation with cross-section data, namely, that individual technical efficiency cannot be estimated consistently.

by Alvarez and Perez (2000) and Herrero and Pascoe (2001).

Alternatively, TE can be modeled as a parameter by writing $\alpha_i=\alpha-u_i$. The production function then becomes:

$$y_{it} = \alpha_i + x_{it}\beta + v_{it} \qquad (3)$$

where the α_i are the individual effects. This model can be estimated by OLS including vessel-specific dummies or, equivalently, by OLS after subtracting individual means (Within transformation). It should be noted that these two estimation methods preclude the use of any time-invariant variables other than the vessel dummies.

If the output is in logs, technical efficiency indexes for each vessel can be calculated in model (3) using the estimated individual effects (Schmidt and Sickles, 1984):

$$TE_i = \exp(\hat{\alpha}_i - \max\hat{\alpha}_j) \qquad (4)$$

Squires and Kirkley (1999) and Alvarez and Perez (2000) are the only papers to use the fixed effects estimator with fish data. This is surprising since the OLS estimator for this model is always consistent. This is very important in efficiency models since inefficiency is usually modeled as a stochastic term (random effects or stochastic frontier). In this case, consistency of the estimators requires inefficiency not to be correlated with the included explanatory variables. Therefore, a Hausman specification test, as suggested in Hausman and Taylor (1981), has to be performed.[3]

The problem with the fixed effects model is that there are very few inputs which can be varied by the skipper, since the boat characteristics are fixed and some possible choice variables, such as net or line length, are usually fixed through regulations. Therefore, since in fishing most inputs are fixed, their effect is swamped into the fixed effects. For this reason, the normal interpretation of the fixed effects as reflecting differences in TE must be done with caution since other important effects are included there. One solution to this problem is to employ the two-stage approach developed by Alvarez and Gonzalez (1999) which consists in regressing the estimated fixed effects on a set of time-invariant variables. In this way the effect of time-invariant factors is taken away from the fixed effect before calculating the TE index.

[3] Surprisingly enough, despite the vast amount of papers that estimate stochastic frontiers, the number of those that carry a Hausman test is minimal.

If one is interested in the marginal productivity of particular time-invariant characteristics the Hausman-Taylor instrumental variable estimator can be used. This estimator has the problem that the necessary instruments have to be constructed with the means of variable inputs, which, as pointed out before, in fishing are very rare.

The main features of the papers that have followed a parametric approach to estimate production frontiers in fisheries are summarized in Tables 1 and 2. Table 1 describes the general characteristics of the papers while Table 2 contains the main specification and estimation issues.

Table 1.- Papers that estimate TE in fisheries using a parametric approach

Paper	Year	Main Species	Fishing Gear	Country	Years	Boats	Data
Kirkley, Squires, Strand	1995	Scallop	Dredge	USA	87-90	10	Trip
Kirkley, Squires, Strand	1998	Scallop	Dredge	USA	87-90	10	Trip
Coglan, Pascoe, Harris	1998		Trawl	England	92-95	63	Monthly
Campbell, Hand	1998	Tuna	Pole line	Solomon	88-94	115	Monthly
Squires, Kirkley	1999		Trawl	USA	86-89	26	Annual
Sharma, Leung	1999	Tuna	Long line	Hawaii	1993	91	Trip
Grafton, Squires, Fox	2000	Halibut	Longline	Canada	88,91,94	107	Annual
Eggert	2000	Lobster	Trawl	Sweden	1995	61	Trip
Alvarez, Perez	2000	Hake	Bottom nets Long line	Spain	1999	12	Daily
Susilowati et al.	2000		Purse Seine	Indonesia	1995	49	Trip
Pascoe, Andersen, de Wilde	2001	Sole Plaice	Trawl	Holland	80-97	130	Annual
Coglan and Pascoe	2001		Trawl	England	92-95	63	Monthly
Herrero, Pascoe	2001	Schrimp	Trawl	Spain	1985	59	Monthly

Table 2.- Specification and estimation characteristics of efficiency papers in fisheries

Paper	Output[1]	Main Inputs	Panel data	Form[2]	Individual effects	Time effects	Model[3]	Technical Change	U_{it}	g
Kirkley, Squires, Strand	Q	Crew size, Trip length, Stock	Y	TL	N	Y	ML	N	HN	0.63
Kirkley, Squires, Strand	Q	Crew size, Trip length, Stock	Y	TL	Y	Y	BC95	N	TN	0.78
Coglan, Pascoe, Harris	V	Length, HP, Hours fished, Stock	Y	TL	N	N	BC95	N	TN	0.53
Campbell, Hand	Q	GRT, HP, Age, Crew, (x days fished)	Y	TL	N	N	BC95	Y	TN	0.95
Squires, Kirkley	Q	Length, Fuel, Crew size x weeks fished	Y	TL CD	Y Y	Y N	FE RE	N	-	-
Sharma, Leung	V	Crew size,Days fished, Other (fuel, bait, ice)	N	TL	-	-	BC95	N	TN	0.68
Grafton, Squires, Fox	Q	Length, Fuel, Stock, Crew x weeks fished	N	CD	-	-	ML	N	-	0.86
Eggert	V	GRT, Age, Hours fished, Stock	Y	TL	N	N	BC95	N	TN	0.97
Alvarez, Perez	Q	Boat effects	Y	CD	Y	Y	FE, RE, ML	N	HN	0.53
Susilowati et al.	W	GRT, Crew, Hours fished	Y	CD	N	Y	BC95	N	TN	0.33
Pascoe, Andersen, de Wilde	W	Capital, Days fished, Stock	Y	TL	N	N	BC95	N	TN	0.70
Coglan and Pascoe	V	Length, HP, Hours fished, Stock	Y	TL	N	N	BC95	N	TN	0.53
Herrero, Pascoe	Q V	GRT, HP, Number of Trips, Stock	Y	TL	N	N	BC95	N	TN	0.84 0.25

[1] Q: quantity, V: value, W: weighted quantity.
[2] CD: Cobb-Douglas, TL: Translog.
[3] ML: Maximum likelihood, FE: Fixed Effects, RE: Random Effects, BC: Batesse and Coelli.

3. Modeling and estimation issues

In this section we discuss the four aspects of fishing activity mentioned in the introductory section. They deserve specific attention by the researcher in order to correctly estimate technical efficiency in a fishery.

3.1. How to deal with multiple species?

Even though most fishers target one or two species, the non-selective nature of most fishing gears results in some other species being caught (by-catch). Since all of the above mentioned studies choose the production function as the modeling tool, there is a need to convert catches into a single output. Different alternatives exist.

Four papers (Coglan *et al.*, 1998; Sharma and Lueng, 1998; Eggert, 2000; Herrero and Pascoe, 2001) use prices (p) to aggregate all catches into a single output. That is, they use value (V) instead of quantity (y) as the dependent variable. The general formula for values (revenues) is:

$$V_{it} = \sum_{j=1}^{J} p_{jit} y_{jit} \sum_{j} p_{jit} y_{jit} \qquad (5)$$

where subscript j stands for species, i stands for vessel and t for time period.

The aggregation of catches into value is not without its problems. In principle, prices should act as weights which convert quantities into value but without introducing new information. In that sense instead of using prices which are vessel and/or time-specific (p_{jit}) it would be better to use some common prices which are firm and time-invariant (p_j) such as regional averages. In this way one avoids several possible problems. For example, if contemporaneous prices are used to obtain fish sales, some variation is introduced, in the sense that most likely prices depend on catches and therefore are endogenous.

Other papers (Squires and Kirkley, 1999; Pascoe *et al.*, 2001) aggregate catches using multi-lateral superlative indexes, which use revenue shares as weights. These indexes allow prices to differ among firms but assume revenue maximizing behavior and competitive output markets, which may not always apply in the fishing industry.

The simplest alternative is to aggregate catches without any weighting scheme. This implies not to take into account the composition of catch, giving equal weight to all species. This is the solution adopted in most papers.

It is not easy to decide which of these three alternatives is the best since, as it is usually the case, they all have advantages and disadvantages. In my opinion the key is to consider if fishers take decisions regarding catch composition or not. If they do, then value seems to be the logical measure. However, if they are unable to plan composition of catches, unweighted aggregation seems to be a good choice.

Finally, there seems to be a need to discuss if the fact that fishers catch multiple species implies that fishing is a multiple output activity. The fact that fishers obtain species of different value when they lift the nets or line is not very different from the farmer who plants cherries and obtains fruits of different sizes, which carry different prices in the market.

Microeconomic theory has some stringent conditions to consider an economic activity as multi-output. As Beattie and Taylor (1985) put it: “Economic principles for multiproduct production depend in a critical way on whether factors of production are allocable or nonallocable”. Allocable factors are those factors that the amount used in the production of one output can be separated from the amount used in the production of other output. It is difficult to think of an allocable factor in fishing.[4] In any case, if fishing is considered a multi-output activity it seems strange that there are no published papers that use analytical tools specifically suited for this purpose, such as the multiproduct production function or the distance function.[5]

3.2. The importance of fish stock

Some papers include a measure of fish stock as an input of the production function. The idea is that the more fish exists the higher the captures will be. Even though this is right, it does not imply that available stock should be regarded as an input. Production inputs are choice variables, i.e., producers can choose more or less of a given input in order to produce more (or less) and this is not the case of fishing stock.

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[4] Chambers and Strand (1998) consider a model where effort is allocable across species.

[5] A paper that compares these two approaches with the single output case is Alvarez and Orea (2001).

However, even if biomass stock is not an input, its variation is going to affect catches and therefore it seems logical to include it in the production function. How? There are two cases. If boats fish in the same area, then a variation in fish stock will affect all fishers equally. Therefore, the effect of changes in fishing stock are similar to those of technical change, since for example an increase in the stock allows all fishers to produce more fish at any level of input use.[6] In this case, the problem calls for a stock measure common to all producers. On the other hand, if boats fish on different grounds, the stock measure should take this factor into account and be boat-specific.

The question is then how to model the effect of changes in fishing stock. The different alternatives are analyzed below using a simple production model where fishing output of vessel i at time t (y_{it}) can be considered as a function of vessel characteristics (Z_i) and fish stock (S_t). It is assumed that boat characteristics do not vary in time and that stock is common to all boats. Additionally, catches depend on luck and other minor stochastic effects (u_{it}). Therefore, the fishing production function can be written as:

$$y_{it} = f(Z_i, S_t) + u_{it} \qquad (6)$$

If the model is linear, we have:

$$y_{it} = \alpha Z_i + \beta S_t + u_{it} \qquad (7)$$

By construction, $Cov(Z_i,S_t)=0$. It is also assumed that the stock is uncorrelated with luck, i.e., $Cov(S_t,u_{it})=0$.

If there are data on fish stock, then S_t should be included as an explanatory variable.[7] Since stock is not known in most cases, there are several alternatives to deal with this problem. The simplest way is to introduce stock as a random variable uncorrelated with inputs. In this case, the model to be estimated is:

$$y_{it} = \alpha Z_i + v_{it} \quad \text{where } v_{it} = \beta S_t + u_{it} \qquad (8)$$

If the objective is to estimate the effect of vessel characteristics on output, ordinary

[6] This case is similar to that of agricultural production where number of hours of sunlight may affect production. However, very few agricultural production studies include this variable in the analyses.

[7] This is not very common. Only three of the papers that include a measure of fish stock obtained an independent estimate from external sources (Kirkley *et al.*, Grafton *et al.* and Pascoe *et al.*).

least squares applied to equation (8) yields unbiased estimates of α. However, there seems to be interest in estimating the effect of stock on catches (β). If this is the case, two main alternatives exist:

a) Use a proxy for fish stock

In some papers the fishing stock in a given period is estimated as the average catch of all (or some) boats in that period.[8] That is,

$$\hat{S}_t = \frac{\sum_i y_{it}}{N} \qquad (9)$$

Using equation (7) the stock index becomes:

$$\hat{S}_t = \alpha\bar{Z} + \beta S_t + \bar{u}_t \qquad (10)$$

where $\bar{u}_t$ is the average luck of all boats in period t. It should be noticed that $\bar{u}_t$ is not necessarily zero.[9]

In equation (10) one can solve for βS_t and substitute this value in equation (7):

$$y_{it} = \alpha Z_i - \alpha\bar{Z} + \hat{S}_t + (u_{it} - \bar{u}_t) \qquad (11)$$

This is the expression of the production function implied by the functional relationship between the stock index and the true stock given in (10). Equation (11) can now be compared to the estimated production function, which is :

$$y_{it} = \alpha' Z_i + \beta' \hat{S}_t + v_{it} \qquad (12)$$

Comparing these two last equations it is easy tio see that the estimated β' should be close to 1. This is so, because the construction of the stock index based on captures implies that any variation in the stock will be captured. This is a very important underlying assumption, apparently overlooked by previous literature.[10]

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[8] For example, Coglan *et al*. (1998) create a stock index based on "the average value per hour fished of the boats that operated in the same month in the same area using the same gear". Eggert (2000) calculated a stock proxy as "the overall average landing value per unit effort on a monthly basis". Therefore the first measure seem to be boat and time specific (S_{it}) while the last only has time variation (S_t).

[9] However, E[$\bar{u}_t$]=0.

[10] The same result is obtained if a Cobb-Douglas production function is estimated using the geometric mean of catches as a proxy for stock.The geometric mean of catches is:

From the estimation point of view, introducing a proxy of fish stock based on average catches can sometimes lead to endogeneity problems This problem resembles the most general question of explaining individual behavior by the group average. Manski (1995) analyzes the specification and estimation problems of this approach.

b) Use time dummies to control for the effects of stock variation

If stock is common to all boats, one can write:

$$y_{it} = \alpha Z_i + \gamma_t + u_{it} \qquad (13)$$

where γ_t are time effects. If the panel data set is short in the time direction, the time dummies will probably pick up only the effect of stock changes, otherwise they will also pick up pure neutral technical change.[11]

This model can be estimated by subtracting individual means.

$$\bar{y}_t = \alpha \bar{Z} + \gamma_t + \bar{u}_t \qquad (14)$$

Thus,

$$y_{it} - \bar{y}_t = \alpha(Z_i - \bar{Z}) + (u_{it} - \bar{u}_t) \qquad (15)$$

Equation (15) basically says that the difference in catches for boat i in period t from average catch will be due to the difference in boat characteristics with respect to their mean. OLS applied to equation (15) will yield unbiased estimates of α.

$$\tilde{S}_t = \sqrt[N]{y_{it} \ldots y_{Nt}}$$

Taking logs, one obtains the average mean of the log of catches:

$$\ln \tilde{S}_t = \frac{1}{N} \sum_i y_{it} = \overline{\ln y_t}$$

Summing over i and dividing by N in equation (7) written in logs, yields:

$$\overline{\ln y_{it}} = \alpha \overline{\ln Z} + \beta \ln S_t + \bar{u}_t$$

Solving for $\beta \ln S_t$ and substituting back:

$$\ln y_{it} = \alpha(\ln Z_i - \overline{\ln Z}) + \ln \tilde{S}_t + (u_{it} - \bar{u}_t)$$

It can be seen that if a model in logs is estimated using the geometric mean of catches as a proxy for stock, one will get a coefficient of 1 for this variable.

[11] This specification considers the stock as non-stochastic. A more realistic setting would be to consider γ_t a random variable and add a second equation to describe its behavior. One possibility

The time effects can be recovered taking into account that:

$$\gamma_t = \bar{y}_t - \alpha\bar{\bar{Z}} - \bar{u}_t \tag{16}$$

Therefore, a consistent estimator of the time effects will be:

$$\hat{\gamma}_t = \bar{y}_t - \hat{\alpha}\bar{\bar{Z}} \tag{17}$$

The difference between the two estimators of fish stock can be seen calculating their respective expected values. The expected value of $\hat{S}_t$ in equation (10) is:

$$E(\hat{S}_t) = \alpha\bar{Z} + \beta S_t \tag{18}$$

This implies that $\hat{S}_t$ is a biased estimator of S_t, since what it is fished on average depends on the average fishing effort ($\bar{Z}$).

On the other hand, using equation (16) the expected value of $\hat{\gamma}_t$ is:

$$E(\hat{\gamma}_t) = E(\bar{y}_t) - \bar{\bar{Z}}E(\hat{\alpha}) \tag{19}$$

Since, $\hat{S}_t = \bar{y}_t$, substituting equation (18) into equation (19) yields:

$$E(\hat{\gamma}_t) = \beta S_t \tag{20}$$

Therefore, the time effects are unbiased estimators of the effects of fish stock on output.[12]

3.3. The importance of time aggregation

The data sets in most of the studies considered in Tables 1 and 2 form an unbalanced panel. The sources of variation are vessels and time. Most of the studies have data at the trip level, but they end up aggregating at the monthly level.

One consequence of aggregation in time is that the R^2 is higher. The reason for this is because time aggregation implies that the variance of the random term becomes a smaller fraction of the total variance. This is shown below.

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is: $\gamma_t = \phi\gamma_{t-1} + w_t$

[12] If the boats fish in different grounds, the stock is area-specific. In this case, the stock could be estimated using a combination of time and area dummies.

The starting point is the following stochastic production function:

$$y_{it} = \beta x_{it} + u_i + v_{it} \qquad (21)$$

where i indexes firms and t time. The Xs are non-stochastic. As usual, u represents inefficiency, which is assumed to be time-invariant and v is the typical random noise. The underlying assumptions are Cov(u,v) = Cov(x,u) = Cov(x,v)=0. For simplicity we will also assume that the panel is balanced.

Note that in this model:

$$\mathrm{Var}(y_{it}) = \mathrm{Var}(u_i) + \mathrm{Var}(v_{it}) = \sigma_u^2 + \sigma_v^2 \qquad (22)$$

Let's assume that t represents days and that for some reason the researcher is interested in estimating the model with monthly data. Then, the model with monthly variables is:

$$\sum_{t=1}^{T} y_{it} = \sum_{t=1}^{T} (\beta x_{it} + u_i + v_{it}) \qquad (23)$$

Since $\mathrm{Var}(\sum u_i)=T^2\sigma^2_u$ and $\mathrm{Var}(\sum v_{it})=T\sigma^2_v$, the variance of the transformed dependent variable is:

$$\mathrm{Var}\left[\sum_{t=1}^{T} y_{it}\right] = \mathrm{Var}\left[\sum_{t=1}^{T} (\beta x_{it} + u_i + v_{it})\right] = T^2\sigma_u^2 + T\sigma_v^2 \qquad (24)$$

Now it is easy to prove that the variance of the inefficiency term is a larger proportion of the total variance. Using the well known γ ratio, we can compare its value with daily (γ_{days}) and monthly data (γ_{months}).

$$\gamma_{days} = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \qquad (25)$$

$$\gamma_{months} = \frac{T^2\sigma_u^2}{T^2\sigma_u^2 + T\sigma_v^2} = \frac{T\sigma_u^2}{T\sigma_u^2 + \sigma_v^2} \qquad (26)$$

The second ratio is larger than the first one, implying that the value of γ is larger the higher the level of aggregation along time. Therefore, γ ratios must be interpreted carefully since they depend on the level of aggregation of the data.

When aggregating captures during a certain period of time, it has to be taken into account that not all vessels have been fishing the same number of days (or hours). Therefore, a control variable, such as number of days (hours) fished has to be included. A possible problem may occur with this variable if trip length is endogenous. That is, if skippers plan the duration of the fishing trip in advance and stick to plans regardless of how successful the trip is, then trip length is exogenous. However, if the length of the trip depends somehow on how much fish is being caught, then trip length is endogenous, causing possible estimation problems.

3.4. The role of fishing ground

Since Farrell, it has been traditional to consider technical inefficiency as the reflection of firms not exploiting the technology to its potential, i.e., they do things wrong given a common state of knowledge.

In a fishery, the main decision taken by skippers is the selection of fishing ground. Given that boats are free to choose any fishing ground, this seems to be the most important source of inefficiency in a fishery. However, sometimes boats share fishing ground, which gives rise to a different but also interesting concept of technical inefficiency: the comparison of performance given fishing ground.

To our knowledge, so far, the papers that have studied efficiency in fisheries have not taken into account this important source of inefficiency.

4. Conclusions

In this paper we have analyzed modeling and estimating issues in the study of productive efficiency in fisheries. In particular, we study the implications of multiple species, biomass stock, trip length and the choice of fishing ground. The paper shows, among other things, that some of the usual proxies for fish stock are biased and that the effect of aggregating data along time is increase the proportion of ineffiency in the total variance.

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