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Investment and factor remuneration in small-scale fisheries

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Abstract

Investment behaviour is a complex process which plays a major role in fisheries dynamics because it determines the size of the fishing fleet. The purpose of this paper is to examine the consequences of the main characteristics of fishing activity on investment. The theoretical dynamic model of a fishery shows us the "bang-bang" pattern of investment. Furthermore, fishing activity has a high intrinsic variability. Thus, the system in which income is shared between the crew and the ship owner is also considered as a way of sharing risks and so reducing the variability of investment return. Finally, the type of investment financing (subsidies, loans) can strongly stimulate fisheries dynamics but can also have some undesirable effects.

Investissement et rémunération dans les pêcheries artisanales

Résumé

L'investissement est un processus complexe qui joue un rôle majeur dans la dynamique des pêcheries, puisqu'il détermine la dimension des flottilles de pêche. L'objet de cet article est d'étudier les conséquences des principales particularités de la pêche sur l'investissement. Le modèle dynamique d'exploitation des pêcheries nous montre le type "bang-bang" de l'investissement. Par ailleurs, la pêche a une forte variabilité intrinsèque. Ainsi, le système de répartition à la part entre l'équipage et l'armateur peut être considéré comme un système de partage du risque qui réduit la variabilité de la rentabilité de l'investissement. Enfin, le mode de financement (subventions, emprunts) peut encourager positivement la dynamique des pêcheries, mais peut aussi avoir des effets indésirables.

Introduction

Fishing activity depends on the development both of capital (fishing fleet) and of resources. Net investment is a way of increasing the fishing capacity and so investment behaviour plays a major role in fisheries dynamics.

Small scale fisheries developed considerably in France during the eighties : fish catches grew from 1,5 to 2,9 billions of francs between 1985 and 1990 which represents 75 % of the total landings in France this last year. During the same period the fishing capacity of the small-scale fishing fleet increased by 7,8 % in GRT terms and by 11,7 % in KW terms[(1)]. Now, the multi-annual guidance programme (MAGP) of the EEC aims to reduce fleets in order to avoid overfishing.

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(1) Horsepower of the ship's engines.

Several questions arise concerning fisheries management and investment behaviour. In the first section we present the theoretical background of investment decision to point out the "non-smooth" process of capital accumulation in fisheries.

In the following sections we address in particular two major problems concerning return and investment. We examine the consequences of the system of income-sharing between the crew and the ship-owner which reduces the return variability and subsequently the investment risk. In the last section, we focus on the influence of the type of investment financing on fisheries dynamics.

Theoretical background of investment decision

The purpose of this section is to analyse the investment process in a bio-economic model. More details about this model are developed by Clark (1985) and Junqueira-Lopes (1985).

We consider a single species model where x(t) is the biomass, p (fixed) is the unit price of harvest h(t), c(x) is the cost per unit of catches and δ is the discount rate. K(t) represents the capital, I(t) the investment, γ the depreciation rate of capital and S(t) the final value of the ships.

The model could be expressed as :

$$
(1)\quad \begin{cases} \max \int_0^T e^{-\delta t}\{[p - c(x)]h(t) - I(t) - \gamma K(t) + S(t)\}\, dt \\ \text{with the following constraints :} \\ \dot{x} = F(x) - h \\ \dot{K} = I - \gamma K \\ x(0) = x_0 > 0 \\ K(0) = K_0 > 0 \end{cases}
$$

x(t) and K(t) are the state variables; h(t) and I(t) are the control variables. From model (1), we obtain the hamiltonian :

$$
(2)\ H = e^{-\delta t}\{[p - c(x)]h(t) - I(t) - \gamma K(t) + S(t)\} + \lambda_1 [F(x) - h(t)] + \lambda_2 [I(t) - \gamma K(t)]
$$

and we deduce the canonical system :

(3.1)	$\dot{x} = \frac{\delta H}{\delta \lambda_1}$;	(3.2)	$\dot{K} = \frac{\delta H}{\delta \lambda_2}$;
(3.3)	$\dot{\lambda}_1 = \frac{-\delta H}{\delta x}$;	(3.4)	$\dot{\lambda}_2 = \frac{-\delta H}{\delta K}$;
(3.5)	$\lambda_1(T) = 0$;	(3.6)	$\lambda_2(T) = 0$

Furthermore, we assume that the investment and the harvest are bound together :

$$\begin{cases} 0 \leq I(t) \leq I_{max}(\pi(t)) \text{ (internal financing)} \\ \text{or } 0 \leq I(t) \leq I_{max} \quad \text{(external financing)} \end{cases}$$

$$0 \leq h(t) \leq h_{max}$$

where $\pi(t)$ and h_{max} are respectively the profit and the maximum harvest (which is assumed as a function of the fishing capacity).

To solve the model, we need to use the following switching functions :

$$(4.1) \quad \sigma_I = \frac{\delta H}{\delta I} = -e^{-\delta t} + \lambda_2$$

$$(4.2) \quad \sigma_h = \frac{\delta H}{\delta h} = e^{-\delta t} [p - c(x)] - \lambda_1$$

From equation (4.1), three possibilities appear for σ_I :

$$\sigma_I = 0 \quad => \lambda_2 = e^{-\delta t} \quad => \dot{\lambda}_2 = -\delta e^{-\delta t}$$

which is not consistent with equation (3.4) $\dot{\lambda}_2 = \frac{-\delta H}{\delta K} \neq 0$

$$\sigma_I > 0 \quad => \lambda_2 > e^{-\delta t} \quad => I(t) = I_{max}$$

$$\sigma_I < 0 \quad => \lambda_2 < e^{-\delta t} \quad => I(t) = 0$$

Therefore the control variable I(t) could only be 0 or I_{max}.

Similarly we deduce from equation (4.2) the optimal pattern of the harvest function :

$$(5) \begin{cases} \sigma_h < 0 \; => \lambda_1 > e^{-\delta t} [p - c(x)] \; => h^*(t) = 0 \\ \sigma_h = 0 \; => \lambda_1 = e^{-\delta t} [p - c(x)] \; => 0 < h^*(t) < h_{max} \\ \sigma_h > 0 \; => \lambda_1 < e^{-\delta t} [p - c(x)] \; => h^*(t) = h_{max} \end{cases}$$

The control (I) is called "bang-bang" because the optimal values of investment are its minimum and maximum bounds. Complete study of the optimal investment behavior requires a distinction to be made between several initial states of x(0) and K(0).

If we assume that the initial biomass x(0) is greater than the optimal stock of fish x* (underexploitation of the resource) and that there is no external fund to finance investment, then we distinguish two cases for the investment pattern, according to the initial level of the capital K(0) :

Case 1 : $K(0) < K^*$ (the initial value of capital is suboptimal)

time	I*	K	δK/δt
$0 \leq t < T_1$	$I_{max}(\pi(t))$	increase	$I_{max}(\pi(t)) - \gamma K$
$t > T_1$	γK^*	constant	0

where T_1 is the period where $K = K^* > K(0)$.

Case 2 : $K(0) > K^*$ (the initial value of capital is overoptimal)

time	I*	K	δK/δt
$0 \leq t < T_2$	0	decrease	$-\gamma K$
$t > T_2$	γK^*	constant	0

where T_2 is the period where $K = K^* < K(0)$.

The main issue of this modeling is the "bang-bang" pattern of investment. If we examine the case 1 ($K(0) < K^*$), the capital is the factor which limits the income's increase during the first period ($t < T_1$). Therefore investment has to be the highest. During the second period ($t > T_1$) the resource's availability limits the expansion of income : investment has to be just equal to the fishing fleet renewal.

However, the model is not completely solved because the optimal pattern of capital remains still unknown. Its determination requires an additional equation which links the maximum harvest and the capital :

$$(6)\quad K = \frac{1}{\mu} h_{max}$$

where μ is a coefficient of capital efficiency and $1/\mu$ is the marginal cost of investment.

If we assume that the initial biomass is underexploited ($x(0) > x^*$) and that the initial capital is optimal ($K(0) = K^*$), then the objective function becomes :

$$(7)\ V_1(h_{max}) = \int_0^T e^{-\delta t}\,[p - c(x)]\,h(t)\,dt - \int_0^T e^{-\delta t}\,[I + \gamma K(t) - S(t)]\,dt$$

The second term of equation (7) is the discount value of the fishing capacity during all the periods and is equal to the capital (K). Thus, according to equation (6), the objective function can be written as :

$$(8)\ V_1(h_{max}) = V_2(h_{max}) - \frac{1}{\mu} h_{max}$$

with,

$$(9)\ V_2\,(h_{max}) = \int_0^T e^{-\delta t}\,[p - c(x)]\,h(t)\,dt$$

Thus, the function V_2 is a short-run profit function excluding the capital costs and only considering the direct fishing costs.

Consequently, the optimal value of the maximum harvest h^*_{max} is derived from the following equation :

$$(10.1)\quad \frac{\delta V_1}{\delta h_{max}} = 0$$

i.e.

$$(10.2)\quad \frac{\delta V_2}{\delta h_{max}} = \frac{1}{\mu}$$

and we deduce the optimal pattern K* from (6) : $K^* = (1/\mu)\ h^*_{max}$.

The condition (10.2) means that the optimal pattern implies that the marginal short-run profit is equal to the marginal cost of capital.

Another important issue of this modeling is to explore the relationships between the optimal harvest $h^*(t)$, the optimal maximum harvest h^*_{max} and the optimal capital K* (equations (5), (6) and (10.2)).

The maximum harvest h^*_{max} is bound by the coefficient of capital efficiency μ and could limit h(t) at a suboptimal level ($h(t) < h^*(t)$). On the other hand, a high value of the coefficient of capital efficiency μ could define h^*_{max} greater than $h^*(t)$.

In this case, the fishery exploitation, starting with $x(0) > x^*$, has two stages :

- During the first period ($t < T_1$), both effort and fishing capacity increase. The fishing function is at its top bound $h(t) = h_{max}$.

- At the end of this period ($t = T_1$), the biomass is stabilized at an optimal level.

- Subsequently, the catches can grow during the following period because h^*_{max} is greater than $h^*(t)$.

The over-capacity $K_{over} = (1/\mu)\ (h^*_{max} - h^*(t))$ has to be dropped out of the fleet to avoid overfishing.

Thus, an optimal pattern of fishery development could involve an overoptimal size of the fishing fleet if the capital is very efficient.

In this context, over-capacity should not be considered as a consequence of a common property resources exploitation, because the model that we have solved describes a regulated fishery.

During the first period of the fishery's development, the management policy promotes the growth of effort and investment to reach the equilibrium level of the harvest and the fleet size. Nevertheless, if the marginal cost of investment is very low, the potential effort which is induced by the capital quickly increases and the maximum harvest exceeds the optimal level of harvests.

Variability and the income-sharing system

The investment decision could be strongly affected by the high intrinsic variability of the fishing activity which comes from both resource availability and the market (price determination).

This problem has been examined by Clark *et al.* (1985). The objective of this section is to focus on the influence of the income-sharing system on the investment decision.

The income-sharing system divides the total expenditures of a fishing trip (excluding wages) in two parts (Anderson, 1986) : the running costs directly related to the fishing trip (C_R) and the vessel cost (C_F) related to the ship. The running costs are shared between the owner and the crew. Wages (w) and profit are calculated as follows :

$$(11)\ w = s\,(R - C_R)$$

$$(12)\ \pi = (1 - s)\,(R - C_R) - C_F$$

where s is the crew's share and R is the gross earning. If we consider that a shipowner invests I_0, the net present value of his cash flow is :

$$(13)\ V_3 = -I_0 + \int_0^T \left(\frac{(1\text{-}s)\,(R(t) - C_R(t))\ \text{-}C_F(t)}{(1+\delta)^t} \right) dt$$

From (13), we can calculate the constant unit cost which equalizes V_3 to 0. If we note that the gross earning (R) is the product of the price by the landings h(t), we deduce :

$$(14)\ P_C = \frac{1}{(1-s)} \left[\frac{I_0}{\int \frac{h(t)}{(1+\delta)^t}\,dt} \right] + \frac{1}{(1-s)} \left[\frac{\int \frac{C_F(t)}{(1+\delta)^t}\,dt}{\int \frac{h(t)}{(1+\delta)^t}\,dt} \right] + \left[\frac{\int \frac{C_R(t)}{(1+\delta)^t}\,dt}{\int \frac{h(t)}{(1+\delta)^t}\,dt} \right]$$

As s grows, $1/(1-s)$ is higher and the part of the running costs per unit becomes smaller. The income sharing system reduces the relative influence of the running costs which are generally the most variable expenditures.

The income sharing can be considered as a risk sharing (Platteau, 1989). The variability in gross earnings and running costs (fuel price variations for instance) are shared between the shipowner and the crew. From equation (12), if we assume that the vessel costs have no variance, the profit variance can be written as :

$$(15) \mathrm{Var}(\pi) = (1 - s)^2 \mathrm{Var}(R - C_R)$$

Furthermore, if $R(t)$ and $C_R(t)$ are constant and are independent, the variance of the net present value V_3 becomes :

$$(16) \mathrm{Var}(V_3) = (1 - s)^2 \mathrm{Var}(R - C_R) \frac{(1 - \delta)^T - 1}{\delta (1 + \delta)^T}$$

As shown in equations (15) and (16), both the return variability and subsequently the investment risk are reduced with the income sharing.

To assess the importance of variability and uncertainty in the investment decision, we have run an econometric equation on a representative sample of the biggest French small-scale fishing vessels (12-25 meters length category). Malinvaud (1987) shows that the rate of profit has a greater effect on investment when the risk increases. We have used an accelerator-profit model (Artus & Muet, 1984) on longitudinal data and we obtain the following estimation :

$$\frac{I}{K} = \underset{(1.98)}{0.582} \frac{\pi}{R} + \underset{(1.47)}{0.115} \frac{\dot{R}}{R} + \underset{(0.87)}{0.248} \mathrm{DEP} + \underset{(0.01)}{0.0192} \mathrm{SUB} - \underset{(-0.02)}{0.006}$$

$$R^2 = 0.4 \; ; \; n = 374 \; ; \; \text{period} = 1987$$

$$(\;) = \text{student}$$

where DEP is the depreciation and SUB are the subsidies.

The low value of the coefficient of the variation rate of the gross earning (0.115) is explained by the weakness of constraint for the sea-products demand. On the other hand, the coefficient of the rate of profit is very high (0.58) and is greater than the average value (0.4) for the French industry (Oudiz, 1978).

Consequences of investment financing

Financing is a crucial problem for investment in small-scale fisheries in France. There are three ways to finance shipbuilding : loans, subsidies and the owner's equity. Considering a representative sample of 753 small vessels (12-25 meters length category) between 1971 and

1987, we have computed the three financing shares which are respectively 70 %, 18 % and 12 %. Futhermore, the owner's equity share slows down from 17 % to 10 % during the period. It is therefore important to study the influence of the type of investment financing on fisheries dynamics.

From model (1) the optimal pattern of investment with $x(0) > x^*$ and external financing remains just the same as with internal financing. Two cases are also distinguished according to the initial value of the capital ($K(0)$) :

Case 1 : $K(0) < K^*$

time	I^*	K	$\delta K/\delta t$
$0 < t < T_1$	I_{max}	increase	I_{max} - K
$t \geq T_1$	K^*	constant	0

Case 2 : $K(0) > K^*$

time	I^*	K	$\delta K/\delta t$
$0 < t < T_2$	0	Decrease	- K
otherwise :	some ships are excluded from the fleet	Decrease	- K = number of excluded ships
$t \geq T_2$	K^*	Constant	0

In the first case, the only change from the previous result is that we could reduce the length of the period before T_1 because I_{max} is no longer bound by the profit.

In the second case (overcapacity), the decrease of the fleet could be obtained quickly if some ships were excluded : the final value of the ships S(t) could be increased to reach this objective.

However, the dynamics of investment with external financing raises some questions about the link between the loans and the return. If the investment decision is taken without any long-run investigation on the fish stocks and the future return (myopic decision), we could observe both a high profitability and a dangerous financial situation.

As the overall rate of profit is greater than the rate of interest, the loans stimulate both the capital accumulation and the financial return. Nevertheless, the increase of fishing capacity could exceed the optimal level and could cut down the long-run profits.

Moreover, the loans refund involves a short-run solvability constraint, which becomes very important when the gross earnings slow down (Leon, 1987).

This seems to be the situation of the small-scale fishery in the Bay of Biscay. From 1979 to 1987, the number of ships increased at an 5.1 % annual rate. These investments strongly stimulated the fishing activity : the added value rate grew from 63 % to 68 % between 1985 and 1989 and the rate of return increased from 16 % to 27 %. Unfortunately, the index of financial autonomy (ratio of owner assets and liabilities) decreased from 58 % to 25 % during the same time.

In other respects, the subsidies can have undesirable effects on the ship's costs if there is no (or not enough) competition between the shipyards or the equipment suppliers. In this case, the shipowners would accept a higher cost if they receive some subsidies which cut down their real expenditures.

To test this hypothesis, we selected a sample of 342 trawlers during the 1979-1987 period (Catanzano & Lantz, 1990). We ran an econometric equation to explain the ship's cost by its technical characteristics and obtained the following estimation :

$$\ln(I) = \underset{(6.87)}{1.647} + \underset{(10.3)}{1.332} \ln(L) + \underset{(5.11)}{0.38} \ln(HP) + \underset{(21.8)}{0.093}\, t + \Sigma\, \alpha_i \,\mathrm{Dum}(i)$$

$R^2 = 0.896$; $n = 342$; period = 1979-1987

( ) = student

where L is the ship's length, HP is the horsepower of the engine, t is a linear trend and Dum(i) are dummy variables to differentiate some technical elements (gears and type of hull).

The ship costs are in constant currency; also the coefficient of the trend signifies that there is a 9 % p.a. inflation for the same technical characteristics (L, HP, Dum(i)).

This could be explained partly by the introduction of electronic equipment. Nevertheless, this means that the real cost of investment rises and subsequently that part of the increase in subsidies finances this growth in cost.

Conclusions

The "bang-bang" pattern of investment provides a helpful theoretical background to explain the evolution of investment in small-scale fisheries. The implementation of EEZ in 1977 was a new starting point for these fisheries which increased with a protected market (fresh fish market). The subsidies and financial policy strongly encouraged investment until the mid-eighties. Now, the second multi-annual guidance programme of the EEC (1988-1993) aims at fleet reduction to avoid overfishing. This pattern looks like a sequence of maximum investment (at the beginning of exploitation) and then a lack of net investment.

A second issue to emerge is the long-run link between return and investment which depends on both the resource dynamics and the marginal cost of capital. The two variables, capital and resource, have obviously no common pattern which reach an optimal level. When there is overcapacity and a slowdown of profits, the fishing enterprises suffer financial stress with their heavy debts. Therefore, the external financing of investment which stimulates the fishery development could have some negative effects when the optimum (generally unknown) is exceeded. Thus, the management policy requires to be frequently adapted to fisheries dynamics.

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