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REAL OPTION THEORY AND APPLICATION TO THE FISHERY INDUSTRY: A SURVEY OF THE LITERATURE

Matteo Ferraris and Elena Pagliarino

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Real Option Theory and Application to the Fishery Industry: A survey of the literature[1]

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ABSTRACT: This paper would be a review of the literature of the main and innovative methodologies of evaluation of real investments: the real option approach (ROA). In particular, the aim of this work is to define an optimal methodology and to select the main drivers that permit to make a more accurate evaluation of the investments in the fishery market. ROA methodology comes from the need to overtake the traditional theory of the net present value (NPV) and from the need for the management of a fishery enterprise to adapt to the future market conditions and to the competitive behavior in the changes of the fishery techniques.

ROA was born from the theory of Dixit & Pyndick (1994) that started to use the models of the financial option theories in order to evaluate investments in other sectors like oil, energy, ICT, manufacturing. From a theoretical point of view, indeed, real investments are characterized by "irreversibility" and "possibility of delay" since a manager can defer, expand, abandon an initial project in different years of its own operational life. In this context, despite of the financial option models ROA has a real investment as underlying asset. If the enterprise decides to invest in a real investment it means that the enterprise exercises an option and this decision is irreversible. In the context of the Ritmare project, we would use the same methodological approach by using the evaluation of the investments in the fishery market. Our first step is to provide a review of the main papers that focus on ROA in the fishery with some empirical applications. Finally, we also try to underline the main drivers or variables of the literature that permits to use the ROA and to present a possible scheme of work to apply to the fishery market, by using data at regional or municipal level.

KEYWORDS: Real Option Approach, Fishery investments, VAN, Option Pricing Model, Numerical Solution, Profit Uncertainty

JEL CODES: G13, Q22, D8,

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CONTENTS

1. INTRODUCTION

The term "real options" was introduced by Stewart Myers in 1977 and it referred to the application of option pricing theory to the valuation of non-financial, that is, "real" investments with learning and flexibility, such as multi-stage Research & Development and modular manufacturing plant expansion (Myers, 1977). This topic involved many academic researchers starting by 1980's and a number of papers were published about this theory and its possible applications in many fields of the "real" investments.

During the last decades, the interest about this topic increased a lot and, as a consequences, many book and monographs were dedicated to real options from a theoretical and empirical point of view.

Real option became an instrument of capital budgeting and they were implemented to evaluate enterprise in fields like pharmaceutical and new economy. Some popular cases like Tiscali in Italy, put in light how traditional criteria of evaluation were not able to explain the abnormal quotation recorded in the sector ICT, mainly when they provide low or negative operating revenues (Gatti M. & Torricelli C., 2001).

Real options began to attract considerable attention from many fields of economy and industry like the oil and gas industry from a strategic point of view. In many real scenarios, indeed, the managers of new or existent companies have the possibility to make strategic changes such as, for instance, postponement and abandonment, during the lifetime of a project.

An example is that an oil company may decide to temporarily shut down the production when the oil price falls below the extraction cost, whereas the same company may decide to start operation as soon as the oil price rises above the extraction cost. This has happened, for instance, during the Gulf war when several oil fields in Texas and Southern California began operations when the oil price went up sufficiently to cover the relatively high extraction cost (Wang et al. 2012). Also the number of academic articles on real options increased a lot in the last decades.

The strategic options like above are known as Real Options Approach (ROA) because the real investment can be seen as coupled with a put or call option. Compared with the traditional "all-or-nothing" Net Present Value (NPV) approach, the real options method takes the advantage of "wait-and-see" and reacts strategically when uncertainty resolves over time.

The investors can leave unfavourable investments by considering the possibilities like abandonment, deferment a project. As a result, the real options approach can increase the value of a project, when compared with the less flexible NPV approach. The standard Discounted Cash Flow (DCF) criteria often undervalue investment opportunities, which would lead to myopic decisions, underinvestment and eventual losses of competitive positions because important strategic considerations are either ignored or not properly valued (Wang et al. 2012).

ROA could be a very complicated method in order to evaluate a variety of real options. In real life, people can still make different kinds of mistakes by applying the model wrongly, or misunderstanding the real options nature of a particular project. Therefore, it is crucial to know whether the real options approach makes intuitive sense to investors, and if not, what are the possible pitfalls. For example, in the oil industry it is important to perform valuations as accurate as possible since, given the magnitude of the stakes in such investment, even a tiny valuation mistake may cause large financial losses. But as observed by Dixit & Pindyck (1994), even the government can arrive too low valuations, if they apply the NPV instead of real options method (Wang et al. 2012).

Behind to the theoretical work on ROA approach, empirical models of ROA have been still scarce. Indeed, it can be difficult to obtain reliable data on components of the real options approach, such as the current and future value of an underlying asset, and the investors' expectations of the future cash flows.

From a theoretical point of view, the investment decisions in the ROA share three important characteristics.

Fist, the investment is partially or totally irreversible (since the initial cost is sunk and you cannot recover it). Second, there is uncertainty over the future rewards from the investments. Third, there is some leeway about the time of the investment (you can postpone the action to get more information about the future).

Real investments are characterized by "irreversibility" and "delayable", as in the financial investments. Moreover, a manager could defer, expand, contract, abandon (for salvage values) or otherwise alter a project (switch among alternative inputs or outputs) at various stages of its useful operating life (management flexibility).

The "irreversibility" is given both by the peculiarity of the invested capital with respect to the production of the firm and by the existence of institutional constraints. The necessary expenses to realize the investment, once they incur, are unrecoverable (sunk costs) or they could be in a minimum part. Irreversibility makes the investment sensible both to the future values of the decisional variable (i.e. market prices, interest rates, operational costs and investment timing), and to the degree of sustainability and credibility of economic policy. This implies that it occurs a deep preliminary analysis of the project.

The "delay" of the investment is the possibility to postpone the investment decision and it could be a sort of opportunity cost: to delay a decision could favour competitors' action on the one side, but also could permit to obtain new information about some key random variables.

In this sense, irreversibility and delay make investment opportunity similar to a financial call option that guarantees a right to postpone the decision of a purchasing after seen the evolution of the market, since the exercise of the option is an irreversible action.

The investment decision is the decision to pay a sunk cost today and in return gets an asset whose value can fluctuate in the future. This is very similar to the theory of the financial option – i.e. a *call* option, when the investor *buys* the right not the obligation to purchase an *underlying* asset of fluctuating value for a present exercise price.

The option can be exercised ("in the money") if the value of the underlying asset rises above the exercise price (in this case, investor has a profit derived by the difference between the value of the asset and the value of the exercise price): only when the value of the asset rises sufficiently above the exercise price (option is “deep in the money”), exercise is optimal[2].

The traditional NPV or, better, the expected net present value (ENPV), cannot be considered the most significant representation of the project when the market is uncertain and the technology is flexible, that is, when management action can be without increasing the costs of production in a meaningful way. Hence, the role of the option value results decisive in a strategic investment overview. Real options provide a method of evaluation of investments coherent with the practice of the financial markets (Contingent Claim Analysis and Black & Scholes) in order to analyse “complex” payoffs related to the real activities.

It is also possible to say that option value was born from the failure of the traditional capital budgeting (DCF, NPV) and from the need of the management’s flexibility to adapt its future actions in response to altered future market conditions and competitive reactions. “With uncertainty and irreversibility, NPV rule is often wrong, very wrong. Option theory gives better answers” (Dixit A.K. & Pindyck R., 1994).

“Traditional discounted cash flow approaches to appraisal of capital-investment projects, such as the standard net-present-value rule, cannot properly capture management’s flexibility to adapt and revise later decisions in response to unexpected market developments” (Trigeorgis, 1996).

This paper would present a review of some of the main papers about ROA approach starting by the models used in different fields of economy in order to evaluate some of the main results of ROA applied to the fishery market.

The structure of the paper is the following. In the next section we briefly review the main research on real option applied to different fields of real investments. Section 3 provides a generic theory about real option from a mathematical point of view and gives a first taxonomy of ROA. Setion 4 make an overview about the real option approach applied in the fishery market and try to explain what are the main advantage with respect to other models of investment evaluation, like NPV. Finally, Section 5 provides some conclusion and some possible future methodological approach to use ROA in the fishery market.

2. A BRIEF REVIEW OF THE LITERATURE

Before the formal introduction of the theoretical real options technique, we would remind that many corporate managers and strategists have dealt with the ideas of managerial flexibility and strategic interactions on an intuitive basis. Myers (1977) first proposed the idea of thinking of discretionary investment opportunities as growth options.

Some general aspects of real options framework have been developed by Trigeorgis & Mason (1987), Trigeorgis (1988) and Amaran & Kulatilaka (1999). More specific applications of the real options framework to various investment problems include real estate development (Titman 1985, Williams 1991), lease contracts (Grenadier 1995), oil exploration (Paddock, Siegel &

[2] We use “optimal” considering also a remote possibility of call option that can be exercised in order not to realize just a financial operation but for, i.e. ownership and governance aims in a company.

Smith 1988), and research and development (Dasgupta & Stiglitz 1980).

Trigeorgis (1996) studied the impact of competition on the optimal timing of project initiation using option methodology and Boyer et al. (2004) make a comparison of the different theories of ROA in the strategic competition.

Ankum and Smit (1993) consider that an investment strategy encompasses a sequence of tactical investment projects, of which several may yield a low return when considered in isolation. Ankum and Smit use numerical examples and the binomial valuation method to study the effect of competitive interactions on the decision of waiting to invest.

Perotti and Rossetto (2001) investigate the timing and the valuation of strategic investment aimed at enhancing entry opportunities in related market segments. As demand is uncertain, entry options should be exercised at the optimal time, trading off the market share gain against the option to wait until more information is revealed, while anticipating competitors' entry behaviour. When the strategic investment grants a strong competitive advantage, the innovator can optimally choose the timing of entry; in case of weaker advantage, the investing firm enters just before its competitor would.

Recent applications of real option approach have been implemented in many fields of economic theory. Some researchers have evaluated the strategic value of the investment in renewable energy R&D (Lee, D.J. et al 2011) where the decision maker has a compound option to invest, abandon or delay of investment itself, according to the changes of markets circumstances through a scenario analysis.

Findings from experimental studies on real options come from Yavas & Sirmans (2005), who applied a simple two-stage investment setting to test for optimal timing by the subjects. They also measured the premium associated with the real options components of an investment and examined how this premium is correlated with uncertainty about future cash flows from the investment. Their results again provide mixed evidence regarding the descriptive validity of real options theory. On the one hand, most subjects seemed to be too optimistic and entered the project too early when compared with the theoretical optimal timing. On the other hand, in the bidding experiment, their bids for the right to invest in a project were in general close to the theoretical level, and reflected the value of the real options embedded in the project. Moreover, the bidding behaviour of the participants was consistent with option pricing theory, which predicts that greater uncertainty about future cash flows increases the value of the project. An interesting phenomenon in the experiment of Yavas & Sirmans (2005) is the learning effect. At the beginning, the bids were too optimistic and hence too high, which is consistent with the typical observation that in-experienced investors tend to be more aggressive and optimistic. The price, however, converged to the theoretical predictions as the experience increases. There was also evidence that some subjects learned to postpone their investment decisions after they gained experience.

While the above studies are among the first empirical tests of option pricing theory, their setups are relatively simple. Subjects typically only make decisions over no more than three periods. Although simplified tasks help to disentangle confounding factors, it is not clear whether one can generalize the results to the more realistic context. This motivates to start an experiment on real option investment in a highly dynamic environment, which is more complicated but also more realistic. Consistent with previous observations, the theory finds real options strategies seem to be more intuitive than the NPV approach, but people differs very much in their strategies.

The ROA theory started to be implemented also in the fishery around year 2000 (Murillas, 2000 and Tomberlin, 2000). Many important decisions in fisheries can be represented as optimal stopping problems, either from the fisherman's perspective (e.g., whether to buy or sell a boat, or whether to participate in a particular fishery) or the manager's perspective (e.g., whether to close a fishery or tear down a dam). The essence of these decision problems is that the decision maker chooses whether to stop one process and start another. They are primarily concerned with issues raised by such lump-sum costs or benefits, examples of which include the price of a new engine, the price of a license to enter a limited-entry fishery, or the opportunity cost of permanently exiting such a fishery. In particular, they consider this last case, a fisherman's exit decision, in which the fisherman can exchange the value of the fishing enterprise for a lump-sum benefit (salvage value) that depending on the circumstance, might be the scrap value of a boat, the sale price of a tradable permit, or simply the capitalized expected value of entering alternative fisheries. Fisherman faces a choice between staying active in a limited-entry fishery, or permanently exiting that fishery. If he chooses exit, he is free to pursue other fisheries (Bosetti & Tomberlin, 2004a).

Li (1998) used the model of option value to analyse the case where the mutual cooperated fishing proprietors will become more conservative in their fishing actions in order to elevate their efficiency in fishing under the uncertainty of fishing resources stock with no another fishing fleets entering into the fishing ground.

Chuang (1999) introduced a discontinuous choice model to evaluate the buyback program of Taiwanese fishing fleets, pointing out that the goal of buyback program can be achieved effectively by considering both economic conditions and the fishing vessel value. Sun (1998) shows that neither the program to restrict the building of new vessels nor a combination of this program with the vessel retirement and buyback program is enough to avoid overfishing for Taiwan's offshore fisheries. She concludes that a passive vessel retirement and buyback program in Taiwan's offshore fisheries is not an effective resource stock recovery program. Moretto (2004) applies a real options model to analyse the vehicle-scrapping programs aimed at encouraged the retirement of old cars. Considering stochastic net benefits of driving service, vehicle owners would wait for the net benefit information, which may substantially affect the scrapping time.

3. REAL OPTION APPROACH IN COMPARISON WITH THE NPV APPROACH

3.1 The Theory

In order to evaluate the power of ROA we have to put in light the limits of the most famous, applied and widespread financial criteria of evaluation, the NPV and the capability of ROA to capture the value of a flexible management in a single investment.

Recent theories that use ROA try to explain the limit of the NPV with respect to the ROA approach.

According to Murillas (2000), for instance, the Real Options this theory is preferred to the traditional discounted cash flows methods, because the cash flows will probably differ from what management expected initially due to the high volatility of the fishing resource price; in fact, investors or managers may have valuable flexibility to alter the exploitation and investment policy in the fishery.

From a theoretical point of view, the NPV provides an index of economic convenience of the project and it is obtained by subtracting the present value today of the future cash flows during the life of the project with the value of initial investment, as the following formula:

$$NPV = \sum_{s=1}^{\infty} \frac{CF_s}{(1+i)^s} - I_0$$

where *I* is the investment value in time zero, *i* is the interest rate and *CF* is the cash flow for each time[3].

The NPV represents the adding monetary earning respect to the interest to actualization that represents the cost of capital needed to the project.

The project is evaluated as good or not depending on NPV is positive or negative, respectively. Despite the simplicity of computation of this index, NPV presents two elements of criticality: the right prevision of the cash flows and the choice of the interest rate. Usually, the interest rate is chosen as the weight average cost of the capital (r_{wacc}). The NPV is a criteria that:

1. Provides a negative evaluation of the uncertainty, because activities with high risk receive a low evaluation;
2. Is static, because it does not predict the possibility to introduce a variation of the project during its life;
3. Is deterministic, because it predicts an only prevision of the cash flows generated by the project.

The static nature of NPV is due to the fact that it hypothesizes if there is irreversible investment (now or never more), it does not evaluate the possibility of postponement and if there is reversible investment, there are not possibilities to modify the initial characteristics (i.e., increase or decrease the productive scale).

On the contrary, in the reality, many investors are characterized by the possibility to realize a “flexible management” of the projects that cannot be captured by the traditional models of evaluation. The different options in many projects have conducted to research and use the theory of the financial options to evaluate a real activity, like ROA.

Let consider the following example. We are deciding whether to build a plant that would produce widgets. The plant can be built quickly, and will cost $1 million. A careful analysis shows that the present value of the cash flows from the plant, if it were up and running today, is $1.2 million. Should you build the plant? The answer is not clear.

Issue is whether you should exercise this option. If you exercise the option, it will cost you I = $1 million. You will receive an asset whose value today is V = $1.2 million. V might go up or down in the future, as market conditions change.

[3] We consider the compounded interest regime.

Compare to call option on a stock, where P is price of stock and EX is exercise price. The option payoffs will be:

- Call option on stock: Max (P-EX, 0)
- Option to invest in Max (V-I, 0).

In order to understand better this theory, we make a simple example (see Gatti & Torricelli, 2001) of an investment with the opportunity of postponement. In other terms, the firm can decide if invest now and start the project immediately or wait for new future information that can modify, in a positive or negative way, the desirability of the project, the decision to invest or not, after the uncertainty is reduced. The value of this opportunity should be taken in consideration at the moment of evaluation, before investing.

In particular, we can say that an investment can generate two different types of returns: one explicit, measurable with NPV, and the other one implicit and not measurable by discounting only the expected cash flows. In order to maintain this implicit return, the NPV has to be adjusted in a way to sure the return by considering the flexible management. The value obtained in this way is called “extended NPV”, computed as NPV + value of the flexibility of the management.

Make a numerical example. Let consider an irreversible investment in semi-conductors where:

I_0 = the value of investment in year 0 = $800;

P_0 = the price of semi-conductors in year 0 = $100;

P_1 = the price of semi-conductors in year 1 =

$$\begin{cases} 150 \quad 150 \quad \ldots \quad with\, prob = q = 0.5 \\ 50 \quad 50 \quad \ldots \quad with\, prob = 1-q = 0.5 \end{cases}$$

in other terms, the price in year 1 can be either 150 with probability q, and remain at this level forever, or it can be 50 with probability 1-q, and remain at this level forever. The interest rate of the model is r = 10%.

3.1.1 NPV approach

If we invest today and we compute the NPV we obtain[4]:

$$NPV_0 = -I_0 + P_0 + \sum_{s=1}^{\infty} \frac{E[CF_s]}{(1+r)^s} =$$

$$= -I_0 + P_0 + \sum_{s=1}^{\infty} \frac{P_1^{up} * q + P_1^{down} * (1-q)}{(1+r)^s} =$$

$$= -800 + 100 + \sum_{s=1}^{\infty} \frac{150 * 0.5 + 50 * 0.5}{(1+0.1)^s} = \$300$$

The value of the NPV is positive, so the investment now is profitable. But now, we compare this value in the case we decide now to wait for investing next year, in time 1, in order to wait for new information. (note that if I wait to invest next year and I see that the price is 50, I decide to not invest because the NPV_0 in this case will be around -$227, so it is negative and not profitable) The value of the NPV (we can call it “extended NPV”) will be:

$$NPV_0^{'} = \left[\frac{-I_0}{1+r} + \sum_{s=1}^{\infty} \frac{P_1^{up}}{(1+r)^s} \right] * 0.5 + 0 * 0.5 =$$

$$= \left[\frac{-800}{1.1} + \sum_{s=1}^{\infty} \frac{150}{(1+0,1)^s} \right] * 0.5 = \$386$$

Also in this case the NPV is positive, but greater than the previous one, and we can see that wait for investing next year is better than investing now. In particular, the difference between the two values will be:

[4] Remember that the sequence $\sum_{s=1}^{\infty} \frac{1}{(1+r)^s} = \frac{1}{r}$

$$NPV'_0 - NPV_0 = \$86$$

This value represents the value of the flexibility.

3.1.2 ROA approach[5]

First of all, let start to define an option. Option is an agreement that gives the holder the right to buy or sell an Asset for a certain price (established now!), at (or by) a certain future time. The owner of a "call" option that gives the owner the right, not the obligation, to make the investment in another period of time, and pay now an exercise price. The underlying asset of the real option, in this case, is the good (oil, gas, fishering…), and the exercise price is represented by the amount of the initial investment.

The ROA has been introduced in literature as an approach that can be able to overtake the limits of the NPV since it evaluates an opportunity of investment like an option that, if it has been exercised, it determines the start of the production/investment. When an enterprise has a possibility to make a decision like this, it does mean that it is the owner of a "call" option that gives the owner the right, not the obligation, to make the investment in another period of time, and pay now an exercise price. The underlying asset of the real option, in this case, is the good (semi-conductors, in our example), and the exercise price is represented by the amount of the initial investment. If the firm decides to invest it means the firm exercises the option and this decision is "irreversible": even if the investment can be sold to another enterprise, it does not possible to re-purchase the option or the money that the firm paid for its exercise. The exercise of the option is optimal when it is "deep in the money", because it guarantees that the value of the returns is greater than the cost of investment. As a consequence, the evaluation of the opportunity of the investment can be done with methods similar to the financial option models.

In our example[6], we use a binomial approach in order to build a risk-free portfolio, with a long position on the opportunity of investment and a short position on "*n*" semi-conductors. The opportunity of the investment plays the rule of the financial option and the semi-conductors are the underlying asset, where "n" represents the delta of the option, that is, the value of the option when change the value of the underlying asset.

The discounted values of the investment in time 1, of the two stages (up and down) are, respectively:

$$PV_1^{up} = \sum_{s=0}^{\infty} \frac{150}{(1+0.1)^s} = 1{,}650$$

$$PV_1^{down} = \sum_{s=0}^{\infty} \frac{50}{(1+0.1)^s} = 550$$

The exercise of the option (that is, to invest) gives to the owner the right to obtain the discounted value of the cash flows of the project and the cost of investment is the exercise price of the option.

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[5] For a more analytical dissertation about option and investment under uncertainty, see Dixit & Pindyck (1994).

[6] Note that we are using as a reference a "European option", where the exercise of the option can be done only at the delivery time. It can be extend the model also to the case of a "American options", that is, contracts that provide the right to exercise the option in every time before the delivery.

As a consequence, the values of the option of investment during the time sequence will be:

$$C_0\ ? = \begin{cases} C_1^{up} = Max\{0; V_1^{up} - I\} \\ = Max\{0; 1{,}650 - 800\} = 850 \\ \\ C_1^{down} = Max\{0; V_1^{down} - I\} \\ = Max\{0; 550 - 800\} = 0 \end{cases}$$

where C_0 is the value of the option to invest in time 0 and C_1 is the payoff of the option in the stage up and down.

Note that, with difference with respect to the financial option, in the payoff of the postponement option, the value of the underlying asset is not represented by the price of the product at the time of exercise but by the discounted value of the cash flows of the project in the case of exercise.

Naturally, if the price increases until 150 (option is "in the money"), the option can be exercised while if the price decreases until 50 (option is "out of the money"), the option is note exercised and the value of the option is null.

The value of the portfolio (W_t) risk-free in time 0 and time 1 is, respectively:

$$W_0 = C_0 - nP_0$$

$$W_1 = C_1 - nP_1 = \begin{cases} 850 - 150n \\ 0 - 50n \end{cases}$$

In order to make the portfolio risk-free, "*n*" has to be such that the value of the portfolio is independent by the evolution of the price of the good, that is:

$$850 - 150n = -50n \Rightarrow n = 8.5$$

$$W_1 = -425$$

According to the theory of the financial option, n represents the delta of the option:

$$n = \Delta = \frac{C^{up} - C^{down}}{P^{up} - P^{down}}$$

Now we consider the cost of the short position on 8.5 semi-conductors as D = r_f*n*P_0 = 0.10*n*P_0, in order to avoid risk-free arbitrage (where r_f is the risk-free interest rate). The return of the risk-free portfolio should be:

$W_1 - D = W_0*(1+ r_f)$

$$r_f = \frac{W_1 - D - W_0}{W_0} \Rightarrow \frac{-485 - 85 - W_0}{W_0}$$
$$= 0.10 \Rightarrow W_0 = -463.64$$

Since:

$W_0 = C_0 - n*P_0$

Finally, we get that:

$C_0 = 386.$

The meaning is that the payoff we get, if we decide to invest in time 0 and if we exercise now the option, is the NPV computed in time 0, that is, 300. However, once we make the investment, we have an opportunity cost of 386. In other terms, the total cost we have to support for investing in time 0 is 800+386 = 1,186, that it is greater than 1,100.

The optimal strategy also in this case is to wait for investing next year, the same result obtained with the extended NPV described before. The theory of the real option provides the advantage to extend the evaluation to the overall enterprise. Indeed, the value of an enterprise can be though as the value of a portfolio of options that can be exercised if some conditions are verified (Gatti & Torricelli 2001).

3.2 A first taxonomy of the real option

The main idea of ROA is to make an investment decision that can be treated as the exercising of an option. Firms have option to invest but they do not need to exercise the option now, since they can wait for more future information. If investment is irreversible (sunk cost), there is an opportunity cost of investing now rather than waiting and the opportunity cost (value of option) can be very large. The greater the uncertainty the greater the value of the firm's options to invest and the greater the incentive to keep these options open. Note that value of a firm is value of its capital in place plus the value of its growth option.

We can determine value of flexibility. For example, flexibility from delaying electric power plant construction, flexibility from installing small turbine units instead of building a large coal-fired plant, flexibility from buying tradable emission allowances instead of installing scrubbers. Option theory emphasizes uncertainty and treats it correctly (NPV rule often doesn't).

For example, the investments in oil reserves could have the following options:

- Option to delay project
- Option to stop before completion
- Option to abandon after completion
- Option to temporarily stop producing

The option approach uses the following stochastic process where a geometrical Brownian motion can represent the value of an asset. Unlike call option on a stock, option to invest may be long-lived, even perpetual. Why does the firm have this option?

To solve this problem, must model the value of the project and its evolution over time. Given the dynamics of the project's value, we can value the option to invest in the project.

Valuing the option to invest requires that we find the "optimal investment rule", i.e., the rule for when to invest. "When" does not mean determining the point in time that investment should occur, it means finding the critical value of the project that should trigger investment.

Real Option can be classified, according to the type of flexibility they generate, in four categories:

1. Investment and disinvestment option. They modify the configuration of an activity (expansion, contraction), they refer to investment timing (speed up or delay an investment) and they are responsible of the changes of firms' strategies (investments in platform or in a short run productive cycle). They include:
    a. Postponement option ('waiting to invest') (McDonald R. e Siegel D., 1986, study the optimal time to invest in an irreversible project, without the possibility to abandon (flexibility) the project once it has been installed)
    b. Exit or abandon option (Myers e Majd, 1990, compute the value of an option to permanently abandon a project with a positive salvage value)
    c. Option of option ('compound and growth option' (Geske, 1979, derives a formula to evaluate an European Call to purchase at the delivery another European Call option)

2. Operational option. They determine the flexibility to react to uncertainty during the use and management of a resource (change of input, of production line, temporary closure of a plant). They include:
    a. Option of expansion or reduction of the productive capability (option to expand or to contract, respectively)
    b. Option of a conversion of production line (option to switch)
    c. Option to temporary suspend
3. Strategic option in a competitive context. They are related to the strategic choice of the moment of adoption of new technologies (pre-emption, war of attrition), able to create a entry barrier for new potential competitors
4. Contractual option. They are clauses that modify the risk profile of the owner of the activity (i.e. clause of liquidation priority or to participation to further investments)

4. IMPLEMENTATION OF ROA TO THE FISHING MARKET: A REVIEW OF THE LITERATURE AND MODELS

In these paragraph, we have selected 6 of the main contributions to the ROA applied to the fishery market by focusing on the content of each paper in order to understand the main aspects of the theories and empirical applications. For each of this paper, we organize the discussion in three steps:

I. *The general description* of the theory of the paper;

II. *The model and main findings*, that is a description of the mathematical model and the technical issues;

III. *Our personal consideration* about the model of the authors.

4.1 "Investment and Development of Fishing Resources: A Real Options Approach" (Murillas A., 2000)

I. The general description

Murillas (2000) analyses how the choice to either invest or exploit a fishery is particularly difficult because of the high uncertainty about the resource price.

In this sense, the use of the ROA to capital budgeting permits to quantify this flexibility, when new information arrives, to change its operating strategy, to defer investments, to shut down (and restart) fishery development.

He presents a general bio-economic model for the value of a fishery and he determines not only the value of the fishery when open and closed, but also the optimal policy for opening, closing and setting the harvest rate.

Moreover, he evaluates the fishery investment opportunity and the optimal investment rule by using data of the Pacific Yellowfin Tuna.

The numerical application shows that the higher the resources stock on the growing section of the natural growth function, the higher the value of the fishery and the higher the resource price, the higher the value of the fishery.

Finally, the sensitivity analysis shows that the lower the tax rate and the convenience yield and the higher the risk-free rate, the higher is the value of the fishery.

The numerical application for the investment valuation models shows that the value of the investment opportunity in the fishery is always lower than the value of the fishery.

Otherwise, the opportunity cost of investing increases even more than the value of the fishery, and hence, there will be less incentive to exercise the investment option.

II. The model and main findings

In his model, he puts the price proportional to the costs according to the risk-free rate, the convenience yield and the volatility of the resource price. The sensitivity analysis highlights that the higher the tax rate and the convenience yield, the more there is incentive to exercise the option because the critical price decreases. On the other side, the higher the risk-free rate is the higher the critical price is.

He starts to describe the dynamics of the resource stock by a difference equation:

$$dX(t) = [F(X(t)) - h(t)]dt$$

where *h(t)* is the production function and *F(X(t))* is the instantaneous rate of growth in the biomass of the fish population. The firm develops the fishery with the following total average cost function: C = C(X).

It is assumed that the firm faces a competitive market for its output, with a spot price S that follows a Brownian motion:

$$\frac{dS}{S} = \mu dt + \sigma dZ$$

where $\frac{dS}{S}$ represents the differential equation of the stock price function and μ is the local trend in the price (stochastic), σ is the standard deviation of the spot price (assumed to be known) and *dZ* is the Gauss-Wiener process.

He puts the following main assumptions to the model:

1. The option to exploit is valued by risk-averse investors who are well diversified and need only be compensated for the systematic component of the risk;
2. There are not arbitrage opportunities;
3. The exchange of assets takes place continuously in time;
4. There exist neither transaction costs nor taxes between the assets exchanged in the market, and all of the assets are perfectly divisible;
5. Markets are sufficiently complete and stochastic changes in S are spanned by existing assets.
6. There is no cost of closing and opening the fishery;
7. The option to exploit the fishery is perpetual, i.e.it has no expiration date;
8. The convenience yield is assumed to be proportional to the current spot price: K = kS.

The value of the fishery, Q, will depend on the current commodity price, S, the fishing stock, X, and the calendar time t is Q = Q(S,X,t).

The opportunity to exploit the fishery is built as a derivative asset. Applying Ito's lemma and to the previous equations, the instantaneous change in the value of the fishery is given by the following equation:

$$dQ = \begin{Bmatrix} Q_S S_\mu + Q_t + \frac{1}{2} Q_{SS} \sigma^2 S^2 + \\ Q_X [F(X) - h] \end{Bmatrix} dt + Q_S S \sigma dZ$$

After a maximization problem of the value of a fishery, he determines not only the deflected value of the fishery when open and closed, but also the optimal policies for opening, closing, and setting the harvest.

4.2 *"Modelling California Salmon Fleet Dynamic" (Tomberlin D., 2002)*

I. The general description

Tomberlin (2002) describes an example of the dynamics of the California commercial salmon fishery in order to describe and predict fleet dynamics in this fishery. The fishery is limited-entry in that the salmon vessel permit must be renewed each year: if allowed to lapse, the permit cannot be reactivated.

He develops two real options models and tests against each other and against a competing hypothesis of exit decisions based on a net present value criterion. He finds the real options models have significantly more explanatory power than the present value model, and taken together suggest that fleet dynamics are more driven by average boat performance than by total fleet performance.

II. The model and main findings

He describes a fisherman active in the California salmon fishery that can have several options: to continue fishing for salmon; to suspend salmon fishing but maintain the right to fish later by purchasing a salmon vessel permit each year; to exit the salmon fishery for good, perhaps prosecuting some other fishery; or to sell his boat, exiting all fisheries.

In his paper, the decision problem is reduced to a simpler form: the fisherman faces a choice between staying in the salmon fishery or exiting, i.e., ceasing to land salmon, thereby giving up the right to resume fishing later.

While the fisherman continues to land salmon, he receives the periodic revenue R (no cost data is currently available in this fishery). Because future revenues are unknown, R is a random variable.

A possible representation of the stochastic process of the evolution of R is a Geometric Brownian Motion (GBM), which implies that percentage changes in R from year to year are normally distributed. The GBM process is formulated as:

$$dR = \alpha R dt + \sigma R dZ$$

where α is the instantaneous rate of change of *R*, σ is a volatility parameter, and *dZ* is a standard Brownian motion[7].

If the fisherman exits the fishery, he exchanges the expected capitalized value of the revenue stream for a salvage value *S*. *S* may be the value of other available fisheries, or of selling the boat. Traditional capital budgeting (present value analysis) involves comparing the salvage value *S* to the capitalized value of expected future earnings (call it *V*) and taking the larger of the two. However, if *V* is stochastic, even if the fisherman is losing money, the prospect that revenues, and thus *V*, will rebound in the future may be sufficient to keep him in the fishery.

The problem facing the fisherman can be formulated as an optimal stopping problem in dynamic programming, the Bellman's equation for which is:

$$F = \max\{S, R + (1+\rho dt)^{-1} E[F(R+dR, t+dt) \mid R]\}$$

That is, the fisherman faces a trade-off between the salvage value S and the value of continuing in the fishery, which is the sum of periodic revenue R and the discounted value of expected future revenues.

They seek the trigger value of R (call it R*), the value at which the fisherman is indifferent between exiting and staying in the fishery (while maintaining the option to exit).

[7] The process thus described is the continuous-time analogue to a random walk with drift.

For R > R*, the fisherman will prefer to stay in the fishery, while for R < R* he will prefer to exit for good.

At the end of the process he finds R* is the value at which the model implies a representative boat will exit the fishery; it provides a basis for an empirical test of the model, described next.

The model suggests that boats experiencing *R* > *R** in a given period will remain active in the fishery, while those experiencing *R* < *R** will exit.

Thus, for each boat, in each period (here, each year) during which the boat is active, comparing observed *R* to *R** provides a prediction of whether the boat should remain active or exit in that year.

This predicted behaviour can then be compared to observed behaviour to assess the model's explanatory power.

The universe of boats considered includes any boat that landed salmon in California at any time during 1981-99. Annual data on California salmon landings and revenues from 1981 to 1999 are from the Pacific Coast Fisheries Information Service (PacFIN), maintained by the Pacific States Marine Fisheries Commission.

Salvage value was calculated as simply the average boat's total revenue (from all species and ports on the West Coast) less its revenue from salmon landed in California. Salmon landed in other states are thus attributed to salvage value, or what fishermen would get if they left the California salmon fishery.

Three competing hypotheses of exit behaviour are examined, in each case assuming a discount rate of 5%.

1. The first hypothesis, "NPV", derived from the net present value model, is that the fisherman chooses the larger of the salvage value (obtained by exiting) or the expected capitalized value of staying in the fishery.
2. The second hypothesis, "TOT REV", is that the fisherman solves the optimal stopping problem, where the parameters governing the evolution of R are those for total fleet revenue. This model suggests that fishermen expect to have a fixed share of total fleet revenue, so that their own fortunes mirror those of the fleet.
3. The third hypothesis, "AVG REV" is that the fisherman solves the optimal stopping problem, where R is governed by the parameters of the average boat revenue process. This hypothesis implies that fishermen care not about the overall fortunes of the fleet, but about the performance of the average active boat.

Each of these hypotheses generates a prediction, for each year for each boat, of whether the boat should exit in that year or not, based on whether the revenue it receives exceeds the threshold value *R**. Because the different behavioural hypotheses generate different trigger values *R**, they can compare the predictive powers of the different models. The data set used for the tests contains 35,466 boat-year observations, for each of which the models' predictions are tested against observed behaviour.

The comparison of the three models provides the following results:

-NPV, the rate of overall correct prediction is 35%,

-TOT REV, the rate of overall correct prediction is 55%

-AVG REV, the rate of overall correct prediction is 73%.

4.3 “Real Options Analysis of Fishing Fleet Dynamics: A Test” (Bosetti V. and Tomberlin D., 2004a)

I. The general description

Bosetti V. and Tomberlin D. (2004a) develop and test a dynamic optimization model of fishermen’s investment behaviour in a limited-entry fishery. Because exit from limited-entry fisheries may be irreversible, the fisherman has an incentive to maintain the right to fish (whether by actually fishing or by purchasing an annual license) even when the fishery is not profitable, in the hope that conditions may improve. This incentive provides at least a partial explanation for excess capacity in fishing fleets, one of the most pressing fisheries management issues in limited-entry (and other) fisheries around the world. To assess the ability of simple financial models to explain observed investment behaviour, they develop a two-factor (price and catch) real options model of the decision problem faced by an active fisherman who has the option to exit a fishery irrevocably.

They think that a possible advantage to this approach is that it provides a mechanism by which investment behaviour can be linked in a real options framework to exogenous factors that affect price and catch separately. For example, international market forces are likely to affect price while having a negligible effect on a local fish stock, while local fish stock dynamics may affect catch directly but have little influence on prices (assuming the demand for a particular fish is relatively elastic). The final result is that with 5,059 observations of decisions in the California salmon fishery in the 1990s, 65% of the model’s predictions are correct, suggesting this approach may be useful in the analysis of fishing fleet dynamics.

II. The model and main findings

The model consider that usually fishermen in California target salmon exclusively, making it reasonable to consider salmon fishing as a project in itself, separate from other projects such as tuna fishing or alternative onshore employment. For this reason, a fisherman remains in the salmon fishery and he receives a profit flow:

$$\pi(P_t, Q_t) = (P_t * Q_t - C_t - L_t)$$

Where P is the price and Q the quantity of fish landed, C is the operating cost flow (which may itself be a function of Q) and L is the periodic license fee.

Because salmon is a limited-entry fishery, the decision to exit the fishery is irrevocable: once the salmon vessel permit has been allowed to lapse, the fisherman cannot get it back and cannot land salmon again (In reality, it is possible for the fisherman to maintain the license while suspending fishing activity, but they ignore that possibility for the purposes of this paper, since it significantly complicates the analysis).

They suppose the price, P, and catch, Q, each follows an independent geometric Brownian motion:

$$dP = \alpha_p P dt + \sigma_p P dz_p$$

$$dQ = \alpha_q Q dt + \sigma_q Q dz_q$$

Where $\boldsymbol{\alpha_q}$ and $\boldsymbol{\sigma_q}$ are the drift and the volatility parameters of the price and quantity processes, respectively.

Assuming an exogenous discount rate ρ, they can apply the methods of stochastic dynamic programming and Ito’s lemma to arrive at a partial differential equation describing the expected value of salmon fishing with an option to quit:

$$\frac{1}{2}\frac{\partial^2 V_1}{\partial P^2}P^2\sigma_P^2+\frac{1}{2}\frac{\partial^2 V_1}{\partial Q^2}Q^2\sigma_Q^2+\alpha_P\frac{1}{2}\frac{\partial V_1}{\partial P}P$$

$$+\alpha_Q\frac{1}{2}\frac{\partial V_1}{\partial Q}Q-\rho V_1+PQ-C-L=0$$

If the fisherman exits the salmon fishery, he receives no current income from salmon and is not permitted any future income, so the value of the salmon fishing project is simply $V_0 = 0$.

Exiting the fishery does, however, enable the fisherman to obtain a salvage value *S*, which could in many fisheries be the sale price of a boat or a transferable permit. In their case, since the project defined by V_1 and V_0 is salmon fishing per se, they define *S* as the capitalized value of profit available to the fisherman from pursuing other fisheries in the time he would otherwise be fishing for salmon.

The problem is to identify $\{P_x,Q_x\}$ combinations at which the expected value of the active project V_1 is the same as the expected value of the inactive project V_0 plus the salvage value $V_1(P,Q) = V_0(P,Q) + S$.

They solved the maximization problem for the exit frontier {Px,Qx} using the finite difference scheme described above. For boats reporting landings in a given year, they then compared actual P and Q to the exit frontier, reasoning that if the model is correct and an active boat falls below the exit threshold, the boat should exit the fishery the following year and stay inactive thereafter. A boat with observed P and Q above the exit frontier in a given year should remain active in the fishery. They compared these predictions to actual behaviour as determined from the PacFIN data, providing a direct test of the model's ability to predict investment behaviour.

Out of a total of 5059 boat-years, the model predicts a boat's status (active or exited) based on the previous year's P and Q in relation to $\{P_x,Q_x\}$ correctly 65% of the time. More informative is the breakdown of correct and incorrect predictions. Very close to all (97%) boats predicted to be active are in fact active, whereas only 12% of boats predicted to have exited the fishery had in fact done so. The dramatic failure to predict exit correctly may be due to flaws in the model that caused the exit frontier to be set too high, thus increasing the number of boats predicted to exit. However, note that their definition of 'active' includes boats that have only temporarily suspended fishing operations, since the 'exited' status is reserved for boats that had permanently given up the fishery.

There are several limitations to the approach taken in this paper, including the use of aggregate data to explain individual behaviour, the fairly arbitrary choice of 6 years as the information set on which to base expectations, and the choice of geometric Brownian motion to represent processes that probably have at least some element of mean reversion (though it must be noted that in the data set available to us neither price nor quantity shows much evidence of mean reversion). They conclude with the observation that such models would almost certainly perform better in more heavily-capitalized fisheries.

III. Our personal consideration

One aspect that worth attention, according to us, is to understand if the fisherman is physical or juridical person, that is, if the enterprise stops when the fisherman ends to fish. In other words, it could be important to understand the "business continuity" of the enterprise, and after apply the ROA according to this typology of classification.

4.4 "Solving real options models of fisheries investment when salvage value is difficult to estimate" (Bosetti V. and Tomberlin D., 2004b)

I. The general description

In this model Bosetti V. and Tomberlin D. (2004b) study the fisherman's exit decision as a framework for exploring solution techniques for real options models focusing on the salvage value of the fisherman, since if the ROA appear to predict actual behaviour reasonably well, it could be often difficult to assess the salvage value of the fishing enterprise (or the opportunity cost of fishing, which when capitalized can be treated as a salvage value). For example, there may be few sales in a market for boats or licenses, and there may be little information on other employment opportunities available to fishermen.

In this paper, they focus on the first two techniques: the solution of real options models represented as systems of nonlinear equations and as partial differential equations. They begin by demonstrating the application of both methods to a very simple representation of the exit decision, then, discuss some of the numerical problems that arise in more complicated models and describe a simple grid search algorithm that is helpful in some circumstances. Finally, they consider salvage value to follow a stochastic process, and again apply both nonlinear equations and finite difference solution techniques to this more general model.

The conclusion of their model is that minimization provides significant advantages if analytical solutions to the partial differential equations can be obtained: they are faster, involve fewer parameters to be specified, and provide more precise estimates of optimal stopping values.

II. The model and main findings

They first present a simple model of the exit decision as a disinvestment problem, and then describe this model's solution by minimization and finite difference methods, including an iterative nonlinear least squares approach that allows rapid solution for a wide range of putative deterministic salvage values. They then allow salvage value to follow its own stochastic process, again exploring this example with both minimization and finite difference techniques. Their general conclusion is that minimization methods are much preferable when they apply, but that in most fisheries applications it will be necessary to resort to finite difference, finite element, or Monte Carlo methods.

The mathematical construction of the model is similar to the model in Tomberlin (2002). In this paper, they propose different alternatives. The first is to consider salvage value as deterministic and the Solution by Nonlinear Least Squares and the second with solution by Finite Difference Approximation. They present a comparison of these two models. Finally, they use a model in which they consider the salvage value as stochastic (more realistic).

a) Simple exit model when Salvage value is deterministic (Nonlinear Least Square v/s Finite Difference Approximation: a comparison).

Consider an active fisherman who continuously faces the choice between fishing and dropping out of the fishery. If the fisherman drops out, he receives a lump-sum salvage value, e.g., the sale value of a permit or boat, but he will not be able to re-enter the fishery. The fisherman does not know either the price or the catch he will obtain if he decides to continue fishing.

They show an example based on data from the California salmon fishery. The data used were fleet average values for revenues and cost proxies (operating and license costs). Maximum likelihood estimates of the parameters α and σ were derived from the revenue series, and they assume a real discount rate of 5% (continuously compounded). They compared two putative real salvage values, $10,000 and $40,000. While these values are very low relative to those that would be expected in a heavily-capitalized fishery, most boats in the California salmon fishery are small and employ simple technologies.

Further, because the fishery for which they are defining the exit option is only open from May to September, the relevant salvage value is what fishermen who leave the salmon fishery could obtain in other fisheries (or other employment) during the summer months. Based on their analysis of the catch of salmon fishermen in alternative fisheries (primarily albacore tuna) in years when they do not catch salmon, the authors believe that these two salvage values are reasonable for this fishery.

The main finding is that the nonlinear least squares approach is clearly preferable to the finite difference approach for the simple example given above. However, in more complicated models the partial differential equations will often not have analytical solutions. For example, different specifications of the stochastic processes for state variables may preclude analytical solution, as may the presence of multiple state variables.

b) Simple exit model when Salvage value is stochastic.

In some contexts, it may be more appropriate to think of salvage value itself as following a stochastic process. For example, the sale price of boats is generally linked to trends and fluctuations in local fish price and catch. Here they follow a simple approach to this problem in which salvage value is treated as a numeraire. While this simplification is not appropriate in all circumstances, it will allow them to examine the implications of introducing stochastic salvage value without facing the numerical challenges raised by a more general specification in which the partial differential equation has multiple state variables. Because it makes more sense to normalize project value by salvage value than to normalize revenues by salvage value, they drop discussion of revenues and costs, and proceed with a single variable V, i.e, the expected capitalized value of profits from salmon fishing. They find a new partial differential equation governing the value of the exit option.

In conclusion, they have demonstrated the significance of different assumptions about salvage value in the application of real options models to fisheries investment, and explored some of the numerical approaches that may be used. To accomplish this, they have ignored several important complications, such as time-varying parameters, parameter uncertainty, multiple state variables (addressed in the deterministic models before), and alternative stochastic processes for state variables.

Their general conclusions are that minimization techniques for systems of nonlinear equations solved the exit problem quickly and accurately, but may be difficult to apply to large systems of nonlinear equations. Finite difference methods did not perform as well specifically they overestimated the exit thresholds and took much longer to generate results. However, they are a reasonable alternative for situations in which the partial differential equation has no explicit solution, as will often be the case. Finally, the reduction of a problem with stochastic salvage value to an equivalent single-factor model enables an exploration of the impact of stochastic salvage value on the estimated exit threshold, but in some cases it will be necessary to solve directly the model in which salvage value and project value both follow stochastic processes.

4.5 "Dynamic participation decisions in California's commercial salmon fishery" (Bosetti V. and Tomberlin D., 2006)

I. The general description

In this paper, Bosetti V. and Tomberlin D. (2006) examine the choice of a representative fisherman to participate in two limited-entry settings, one in which the only alternative to active fishing is permanent exit, and another in which the fisherman has an option to idle the boat, provided he maintains a limited-entry license.

In each of these settings, they consider two possible state variables, the median revenue among active boats and the aggregate fleet revenue, representing two hypotheses about how the fishermen form expectations about the future.

They develop four stochastic dynamic optimization models of participation decisions in which they compute the revenue thresholds at which the representative fisherman would choose to take an available action, e.g., to suspend operations, to resume operations, or to leave the fishery for good.

They find that the representation of limited entry (fish- or-exit models vs. fish-or-idle-or-exit models) has a greater influence on these thresholds than does the stochastic process assumed to be the basis for the fisherman's expectations.

II. The model and main findings

Consider an active fisherman who continuously faces the choice between fishing and dropping out of the fishery. If the fisherman drops out, he receives a lump-sum salvage value, that is, the sale value of a permit or boat, but he will not be able to renter the fishery. The fisherman does not know either the price or the catch he will obtain if he decides to continue fishing.

If this fisherman is assumed to maximize the expected value of the fishing enterprise, his decision problem can be treated as an optimal stopping problem and solved with stochastic dynamic programming. As a consequence, the fisherman's problem is to find a threshold value of the decision variable or variables above which continued fishing is preferable and below which quitting the fishery is preferable.

They suppose that fishermen base expectations about the profitability of their enterprise on some combination of their own personal experience and that of the fleet at large.

However, because most boats that have participated in the salmon fishery do not have enough years of reported data to support standard time series estimation, the authors also will assume that boats act in response to fleet-level variables.

In order to simplify the model, uncertainty about catch and the price of fish will be compressed into single variable, real annual revenue.

The authors show data from the California commercial salmon fishery for the two time series they propose as bases for the formation of fishermen's expectations: median real boat revenue and aggregate real fleet revenue.

While the two series are very highly correlated, they choose to represent them with different stochastic processes for both empirical and theoretical reasons.

The boat median revenue series appears to be well-represented by a mean-reverting process, an intuitive choice that exit of poorer performers during bad times and their re-entry during good times would tend to work against the development of clear upward or downward trends in this variable.

The fleet aggregate revenue, however, does not seem to follow a mean-reverting process, giving more the appearance of a long-term downward trend.

They therefore represent aggregate fleet revenue as a geometric Brownian motion, which allows for a negative exponential decline in fleet revenues that seems a good match for this variable.

Because these different stochastic processes lead to different models of the participation decision, they develop each in turn, beginning with the simpler case of geometric Brownian motion.

a) Simple exit model under geometric Brownian motion

They assume a geometric Brownian motion provides a reasonable representation of fleet revenue, the fisherman's own revenue can be treated as a geometric Brownian motion with the same trend and volatility parameters as the fleet-level variable (since both are rates).

That is, a representative fisherman's revenue evolves as[8]:

$$dR = \alpha R dt + \sigma R dZ$$

The fisherman's problem is to choose, at each instant, the action that will maximize the sum of current and expected future profits. The Bellman's equation is thus:

$$F = \max\{S(R,t), (R - C - L) + (1+\rho dt)^{-1} E[F(R + dR, t + dt) \mid R]\}$$

This equation presents the fisherman's decision as a choice between stopping, in which case he receives a one-time payment of S(R,t), and continuing to fish, in which case he receives the current R, C, and L as well as a stream of expected future net revenues. This Bellman's equation can be solved for the threshold value R_x, below which the optimal decision is to exit the fishery irreversibly. Imposing these boundary conditions they identifies R_x, the revenue level below which exit is optimal. All partial differential equations are solved with finite difference methods.

b) Simple exit model under mean reversion

They turn develop models in which boat revenue follows a different stochastic process and in which the fisherman has more flexibility in decision-making than the simple exit model implies.

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[8] A common objection to representing economic variables with this process is that a positive drift rate implies infinite growth, which can't happen with salmon revenues. However, the process is probably reasonable as a medium-term approximation, and in the case of fleet revenue seems quite a good representation, as this variable has exhibited something like a negative exponential decline over their study period.

An alternative hypothesis regarding the formation of a fisherman's expectations is that the median active boat's performance provides the best picture of what any other fisherman can expect. In their study fishery, the following mean-reverting process appears to be a reasonable representation of the median active boat's real revenue:

c) Option to Idle

The previous simple exit model presumed that once a boat had left a fishery, it surrendered any possibility of participating in that fishery in the future. However, this assumption is not appropriate in many or most cases. In a limited-entry fishery a boat may be able to enter (or re-enter) by purchasing a permit, while under open access conditions the only barrier to entry may be financial (or there may simply be no barriers to entry, in which case their framework is irrelevant).

They develop two models (one for each of the two stochastic processes used above, under geometric Brownian motion and under mean reversion) that reflect the particular limited-entry structure of the California salmon fishery. In this fishery, there is a requirement that a fisherman pay for a salmon vessel permit every year, whether or not he chooses to fish that year. Once the permit lapses, it cannot be renewed except by special appeal to the California Fish and Game Commission. Thus, fishermen have a strong incentive to keep their salmon vessel permits current even when they are not actively involved in the salmon fishery, both because they may later wish to return to fishing and because a current salmon vessel permit adds value to their boat should they decide to sell it. This situation may be represented by a model of the fisherman's problem with three choices: to fish for salmon, to suspend fishing (i.e., idle the boat) while maintaining the option to re-enter the fishery in the future, or to exit the fishery for good. They emphasize that these choices are defined with respect to the salmon fishery only: being active or idle in their model means landing or not landing salmon, and any value derived from other species is represented by the salvage term. The three options interact, e.g., the opportunity to exit the fishery looks less attractive when idling is an option than when there is no idle option. Therefore the thresholds at which idling, re-activation, and permanent exit become optimal must be determined simultaneously.

They first develop a model based on a geometric Brownian motion and then a parallel model based on mean- reverting revenue[9].

They wish to find R_I, the value of R at which it becomes optimal for an active boat to idle; R_A, the value of R at which it becomes optimal for an idle boat to re-activate; and R_X, the value of R at which it becomes optimal for an idle boat to exit. To identify these decision thresholds, they proceed as before, by defining and solving partial differential equations that hold on the continuation range of each discrete decision.

They apply the models described before to the California commercial salmon fishery, using data on revenue and licenses from 1981-2005, with all data converted to year 2000 US dollars. Revenue data are available from landings records kept by the Pacific Fisheries Information Network (PacFIN). Their working data set includes only those boats

[9] The idle boat has already acquired the 'salvage value' represented by the opportunity cost of time spent in the fishery, so that the choice between idling and exiting is not affected by the salvage value.

that i) land at least 5,000 pounds of salmon during at least one year in the study period, and ii) in no year derive more than 50% of their salmon-season revenue from non-salmon species. 664 boats meet these criteria, out of 6,541 that ever report any salmon landings in California. These 664 boats account for 27% of the total value of salmon landings in California during 1981-2005.

In conclusion, the test of model predictions over a 25-year period suggests the model has a fair degree of predictive power, though the test is weak and confidence in the predictive power of their methods would have to come from application to a number of different fisheries rather than from a single test. Among the models they have developed here, those that cast the fisherman's problem as a choice between active fishing and permanent exit generate a higher percentage of correct predictions than those that include the option to suspend operations (simple models), but this is not a helpful comparison since the simpler models do not include the option to idle a boat. Idling is an important option in fishery, and one that is often exercised: during 2000-2005, for example, nearly two-thirds of boats with salmon vessel permits were not actively fishing. The models that include this option (option to idle) generate much lower estimates of optimal exit thresholds of revenue - as low as zero - showing that low license costs and the value of the option to resume fishing in the future make permanent exit from the fishery quite unappealing, at least on financial grounds. This result agrees with the observed level of idling in the fishery and with comments one hears fishermen make about their strategies.

The hypothesis of profit-maximization underlying these models is an adequate explanation for fishermen's participation decisions, as there are no doubt many factors affecting these decisions that the models do not capture at all, such as age, family traditions, and job satisfaction.

By generalizing these models to include both price and catch as state variables, the influence of underlying factors such as oceans conditions or international trade on participation decisions may also be addressed. Thus, while the models no doubt oversimplify the fisherman's decision problem, they are potentially quite useful as an input to management deliberations.

III. Our personal consideration

The model lacks the aspect of the business continuity that could be an important aspect about the idling. Indeed, the idle has a different weight for a manager of a company with respect to the fisherman that has not certainty no the business continuity of the enterprise after her/him.

Moreover, the juridical form of the fishery enterprise could be an important issue to focus, also for the case of "reconversion", as from "pure" fishing to "touristic" fishing.

4.6 "A real options application to the fishing vessel scrapping decision of vessel buyback programs" (Lee Yao-Hsien et al., 2004)

I. The general description

Lee Yao-Hsien et al. (2004) use ROA in order to examine vessel owners' behaviour in deciding whether to participate or not in the vessel buyback programs. The model investigates profit uncertainty in a decision to retire an aged vessel and the underlying value of waiting for new information about the profitability of such a change, which may affect the willingness of vessel owners to participate in the vessel buyback programs. Their analysis shows that the government needs to pay more attention to profit uncertainty, which may invalidate the vessel buyback program that does not take it into account. This also contributes to explain the failure of most of the vessel buyback programs aimed at encouraging the retirement of aged vessels in Taiwan. They also evaluate the value of willingness to accept of vessel owners and its policy implications are discussed. Let provide, now, a brief history of the Taiwan fishery market. In Taiwan, the prohibition policy of building new fishing vessels without quota has been enacted. By 1990 there were 4,824 powered fishing vessels operated more than 15 years, which represent 35% of the total vessels. Because of low efficiency and diminished revenue in Taiwan's offshore fisheries, the smuggling activities have caused fisheries management and society security problems. In order to improve and stabilize this phenomenon, Fisheries administration Authorities have implemented the vessel buyback program for 5 years from 1991 to 1995. Under this program, purchase of 2,337 vessels has granted at NT$12,000 per ton for each vessel. However, the purchased vessels can hardly reach the expected buyback goal of 10,000 powered fishing vessels. This is due to the fact that vessel owners are unwilling to retire those aged fishing vessel automatically, which makes the goal of the program difficult to achieve (Dai, 1997).

Their goal in this paper is to investigate the decision of fishing vessel owners to retire the aged vessels in the presence of profit uncertainty. They accomplish this by using the real options approach to analyse under profit uncertainty how vessel owners are willingly to give up aged vessels. In the paper, the main source of profit uncertainty comes from vessel owners' shortage of full information about evaluating the future state of fish stocks and fish prices. Another source is that vessel owners may obtain political windfall due to the industrial characteristics of fishery in Taiwan. They want to explain why the effect of vessel buyback program was not significant. The program purchased, for example, only 96 vessels representing 0.72% of total number of vessels in 1995.

This model can be used to account for the effect of vessel buyback programs that affect the retirement policy of vessel owners by considering the uncertainty of waiting value.

The paper can determine a vessel owner's willingness-to-accept (WTA) price for a vessel buyback program by the numerical method. The results explain the reason why vessel buyback programs in Taiwan cannot be accomplished effectively. The main explanation for the failure of vessel buyback programs is because the uncertain fishing net profit causes the waiting value that makes vessel owners postpone their willingness of retiring aged vessels.

II. The model and main findings

They model the stochastic fishing profit π following a geometric Brownian motion:

$$d\pi_t = \mu\pi_t dt + \sigma\pi_t dw_t with \mu \leq 0, \pi_0 = \mu$$

where dw_t is the increment of a standard Wiener process; μ is the expected growth rate of the trend value of stochastic process; σ is the standard deviation of the fishing profits. Thus, equation indicates that the fishing profit of a new vessel has been known. The expected fishing profit of vessel owners declines as the vessel ages due to fishing environmental factors or market conditions. For instance, fishing environmental factors (i.e., stock collapse) cause higher risks in fishing operations and result in higher operating costs, or the marketing conditions (i.e., fishing labour shortage) lead to increasing fishing labour costs and the falling-off fishing cost, those factors all influence the vessel owners' net profit π_t.

The vessel owner's fishing profit will be $\pi_t = \pi$ and the expected present value of the stream of fishing profits for the owner will be:

$$F(\pi) = E\left\{ \int_t^{\infty} \pi_s e^{-r(s-t)} ds - \sum_i C e^{-r(s_i-t)} \mid \pi_t = \pi \right\}$$

where C is the cost of buying new fishing vessel for the owner; r is the owner's discount rate; and si is the time when a new vessel is bought and the cost C is paid.

This paper shows that when the government decides to implement the vessel buyback program, it should pay more attention to consider the effect of the profit uncertainty faced by vessel owners. For example, the vessel owner's profit level is the capability of making a profit for an aged vessel, which is the residual value of an aged vessel. Therefore, the buyback price granted by the government should match the vessel owner's WTA. Otherwise the rate of participation in the program will be overestimated. In addition to the profit uncertainty for vessel owners, the government should find out what are the reasons that cause this kind of uncertainty. If the government can restore steady profitability to vessel owners, there will be more incentives for those with lower waiting value to participate in the vessel buyback program. The intuition is that under the profit uncertainty faced by the fisheries industry, the first thing for the government to do is to stabilize the vessel owners' profit. If this is achievable, then the expected goals of the vessel buyback programs can be effectively reached. However, their data shows that the fisheries resources of offshore and coastal fisheries are steadily decreasing due to overfishing.

To protect this trend from worsening, Taiwan's Fisheries Administration has decided to implement the vessel buyback programs continuously in following years, and to increase the price of purchased vessels from 40% up to 270%. This confirms the model's implications. Moreover, they have been informed that the expense of brought trawl equipment this year will be subsidized. This implies that the waiting value has been increased tremendously. It is suggested that the government has to increase the vessel buyback price to make vessel owners having higher incentives to give up their aged vessels.

III. Our personal consideration

When they use the car example (Moretto, 2000) to describe their model, it could be useful to understand better the weight of the ICT on the trawlers. Indeed, the elasticity of the introduction of ICT could be not much elastic (while for the cars is much high).

In the buyback program for fishing boat the price can be due more to the value of the asset as physic structure, not much as its own modernity. In other terms, the "wear" is worth much more than the innovation. Wear and consumption are more linked to mechanical breakdowns than the technical ones. For a fisherman oil can be much expensive: even if modern engines can save money to the fisherman, the cost of technological adjustment is high for the fisherman, moreover if this is imposed by an Authority.

The "aged" term could be substituted by the "used" term. Indeed, while the aged term can be important for the ICT or sectors where the time can make difference also in the case of not-use of the machinery. In other words, an old but not-used boat can have more value of a more young but over-used boat.

5. CONCLUSION AND INDICATION OF THE MAIN DRIVER VARIABLES

With this work, we want to put the basis to elaborate a model for the fishing that can differentiate from the previous model from ad epistemological point of view, and that focuses better on the historical evolution of the fishing market, through a collection of data, geographical and technical, that have affected the growth, migration and evolution of the different types of fishing and of the areas where fishing was most important in the past (inductive/bottom-up approach).

The previous model of ROA seems to under-estimate the historical analysis and the economic and geographical evolution happened in the centuries and, in some cases, they fall in misunderstanding between the "aged" and "used" terms since, for the fishing sector, they have a different meaning and consequences. For example, they are totally different in the fields where elasticity to the change of technology is high, as in the ICT. Indeed, if a boat is stopped for a certain time (idle), it maintains the capability of work optimal respect to a boat that has been used more and more times even if in a brief time: "time" factor, in the fishing market, could be less important than the "exercise". On the contrary, for instance, the "exercise" in the ICT field, has less consequences of the "time", indeed, a personal computer, always switched on for one year, does not loose the capability of work more than a personal computer always switch off for one year.

Moreover, sometimes, elements like the political and biological disposability and the modality of exercise of the activity of enterprise are not taken in consideration in a coherent and homogenous way: for example, in the ROA, the evaluation and the choice of a fisherman that exercises the fishing activity in the form of "individual" enterprise (and he does not have successors that can carry on the activity) will be very different respect to the evaluation and the choices of a manager of a fishing enterprise. The expectation of a physical person defers to the expectation of a juridical person and of a management and the choices computed though the ROA can be diametrically opposite. Once well verified the historical model, it could be possible to implement a top-down model, that is, to take some real cases, random, in order to verify the previsions. It could be important clarify the time and spatial dynamics of the fishing market that we want to consider (i.e. if the area of fishing), and the level of existing technology. On the base of the time frame and spatial frame, some factors can have a value 0 or 1 (absent/present, respectively) according to a fuzzy logic.

5.1 Main drivers collected by the review of the literature

Let show the list of the main driver-variables used in the model seen above.

- -Production function (vessel level or fleet level)
- -Rate of growth of bio-mass of fish population

-Cost function of the fisherman/enterprises (vessel level or fleet level)
-Market price for fish
-Quantity of landed-catched fish (vessel level or fleet level)
-Discounted risk-free rate
-Periodical revenue of an enterprise/fisherman, that is, average revenue among the active boats or aggregate fleet revenue (vessel level or fleet level)
-Salvage value (vessel level or fleet level)
-Operating costs for a fisherman/enterprise (vessel level or fleet level)
-Licence fee (vessel level or fleet level)
-Profit function for a fisherman/enterprise (vessel level or fleet level)

The analysis of the previous variables by distinguishing between 'vessel' level and 'fleet' level can be very relevant also for future empirical works.

5.2 Scheme and layout of work in the fishing and Real Option Approach

1. (Historical) Data mining. Collection of historical data on fishing, in a geographical and economic logic
2. Data. On the base of collected data before, we create a pattern of the system according to 4 categories in a logic sequence:

a. "Material" disposability of the "fish" element, that is, the disposability of the fish resources, with biological-natural characteristics not directly ascribable to the anthropic action, hence, vulnerable to macro-agents not controlled by the human activity like cataclysm

b. "Political-legal" disposability of the "fish" element, that is, the disposability of the fish resource depends from political, supranational, national, local decisions; the agents, in this case, are the political and administrative actors that rule the limits of the space, time quality and quantity of the "cathcable-fish" ("pescabile")

c. Investor or fisherman (who finance directly the activity of the fishing firm):

i. The fisherman and who work directly in the activity of fishing, with an analysis of the juridical form of his fishing activity: if the firm is exercised with a single juridical person, or society, consortium, cooperative, or other not-individual juridical form;
ii. The investor and who has the possibility to finance the activity of firm with his own economic resource (monetary or not, like, for example, who can lend means or materials useful for the fishing activity);
iii. All the other actors that operate in the chain of the "catched-fish", in particular, the employed human resources or human capital;
iv. The Consumer, intermediate or final, of the "catched-fish", that is, the transformer of the fish resource (wholesaler, retailer, final consumer)

d. Rater and opinion leader, that is, all that subjects that have the possibility influence and affect with their own action of "technical" judgment (rater) or tradition-opinion-liking-trend judgment (opinion leader) the demand and supply of the fish good. All the people or group that can affect the actions, opinions and choices of the actors of the previous points.

3. Elaboration of the logic model of the cycle of fishing (catchable/catched) with ROA.
4. Validation of the model with audit/stress test on the real cases by which we have obtained the creation of the model itself
5. Verify of the predictive capability of the model, in particular, with emphasis to the 4 macro-categories of subjects classified before

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