RISK, MARKET IMPERFECTIONS AND THE GROWTH OF AN AQUACULTURAL FIRM

BY

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INTRODUCTION

Economic literature is replete with discussions of risk, market imperfections and firm growth ; often as separate topics. A discussion of risk must inevitably mention Frank Knight's classic contributions to the topic and his dichotomy between risk and uncertainty. Subsequent work has blurred this distinction by introducing subjective probability and expected utility maximization. Subsequent work has also shed doubt on the validity of the expected utility hypothesis in willingness to pay gambles and yet sustained it in the context of aggregate market behavior and "testable hypotheses" (Knez, et al, 1985). to this vast and complex literature we do not aspire to contribute much that is new. Instead we will attempt to apply concepts to a problem in aquaculture using linear programming ; a tool widely used in economics, operations research and industrial engineering.

The application will involve molluscan culture ; specifically the European flat oyster (Ostrea edulis). The choice of species reflects continuing research programs at IFREMER. We are indebted in particular to DR H. Grizel and A. Martin whose meticulous observations over three years have enabled us to calibrate the model to the situation in France.

The model equations are elaborated in a working paper by Gates and Gilly (1986). A copy may be obtained from the authors.

I AGRICULTURAL AND AQUACULTURAL ECONOMICS

A good case can be made for tracing the origins of agricultural economics to the Prussian economist, von Thunen. He used his farm as a source of facts and developed theories to explain these observations. In so doing, he became a founder of the marginal productivity theory and location theory during the period 1826-1863. Early work in North America was initiated by agronomists and evolved into what became known as "Farm Management". In the 1920's, much early work was (necessarily) highly descriptive and statistical. Earlier, the strong opinions of these

empiricists led to a schism within the American Economics Association and the creation of the American Agricultural Economics Association.

We mention this history for two reasons. First, aquaculture and agriculture have some similitaries in research. Both deal with biological organisms which are highly variable ; success depends on highly specific adaptations by the culturist based on adequate factual basis. Secondly, the early emphasis on descriptive statistics was gradually supplemented by techniques variously known as "budgeting", the "method of projection" and the "synthetic method". Such methods received bitter criticisms on the grounds that "synthetic" methods would be abused by practicioners. Adherents of synthetic methods maintained that such methods were "forward looking" ; that one could analyze the probable consequences of alternative scenariis in ways impossible with descriptive statistics. In aquaculture we are often in a similar position where analysis of "what if" questions using synthetic methods is the most appropriate, if not the only technique available. The older budgeting approach has been largely superseded by linear programming, personal computers and "spreadsheets". These extensions enable us to analyze more complex alternatives in more elegant ways, but they do not substitute for the principles developed by the early Farm Management specialists. Among the principles stressed were :

- the objectives (plural) and personal characteristics of individuals farmers must be taken into account ;

- the quantities and qualities of physical and financial resources must be taken into account.

It is a simple exercise to show by examples how these principles preclude any universally "optimal" farm management plan. Unfortunately, such principles were not very instructive and implementation was largely ad-hoc and subjective. Despite aveats against the oversimplicity of maximizing pecuniary rewards, it was precisely such rewards which preoccupied most farm management analysis. A weaker version of "increasing" monetary returns was sustainable because it is widely relevant and leaves scope for tradeoffs against "other" factors.

The french oyster production is mainly due to family owned and artisanal enterprises. Despite wide size variations, these enterprises are usually small, some of them marketing their productions themselves, some other going through larger enterprises to do so. Beyond the primary production characteristics, there are some similitaries between oyster farming and some types of agriculture : most of the labor is due to family manpower, eventually completed with a small number of permanent workers and a sufficient amount of seasonal labor ; moreover, the future of the enterprise is essentially dependant on the family head and on the capital he is able to draw on his own liability and/or know-how. Finally, another similitary is that oyster farming requires permanent attribution of space and the level of production of the enterprise partly depends on the exploited area.

On the other hand, strong differences exist between agriculture and oyster farming :

- in France, attribution of space is not linked with property rights or with private space rental. Culture areas are state owned areas. It can be granted to private firms but, even if this leads to the payment of a fixed fee, this is not based on market relationships (supply and demand). Granting of areas for oyster farming is ruled by regular arrangments. DUMONT (1986) shows that the existing tariff policy results in illegal transaction of concession among individuals at prices far above the official fixed price ; according to DUMONT, the reason is the official price, based on an arbitrary fixed right instead of being based on the marginal value of the area ;

- the level of production of the enterprise does not only depend on the total exploited area and utilised inputs. It is largely dependant on the total growing density of the basin and on water quality, i.e in both case on the other enterprises decisions (should they be oyster farms or others seashore users). These production externalities are similar to those existing in the fisheries sector but we must point out that they are some what different, as every oyster farm is affected in the same way by those externalities. In other words, it is a game where there is only loosers. In their turn, externalities probably lead to different ways in managing risks and uncertainty. Aquaculturists will probably present different attitudes towards risks, depending not only on their own behaviour but also on different informations as the location inside a basin, the number of exploitation and the supposed average density in the neighbourhood.

II REPRESENTING REALITY

II - 1 Basic assumptions

The futility of universal optimality arose again when agricultural researchers extended the "representative farm" (itself a Marshallian concept) to linear programming (LP) models of agricultural sectors. Researchers found insuperable aggregation problems. Several LP aggregation theorems were developed but their significance is in the implausibility of such aggregations. This is not to deny the usefulness of such approaches ; the fact that one cannot prove something always valid does not preclude usefulness based on empirical results. Nevertheless, the power of LP methods appears greatest for disaggregated (individual applications where there is interest in some form of normative question ; how to enhance output, reduce cost, etc. If a substantial dat base-time series and/or cross-sectional does not exist, then synthetic methods are necessary.

The representation of behaviour under risk awaited the evolution of mathematical and statistical formalizations. The expected utility hypotheses leads readily to a first order approximation. Individuals should/would maximize a linear combination of expected income and income (co)variances. In this linear combination, one finds a coefficient of "riks aversion" which weights (presumably,negatively) the variance components of the objective function. This conclusion coincided nicely with the Markowitz quadratic programming model (QP) for portfolio balancing. In an application closer to us, Freund (1956) found much closer congruence between actual cropping decisions of farmers and model optimality using the QP model than expected profit-LP model. His results

are somewhat surprising since his variance estimates were statewide estimates and were probably much different from the variances perceived by individuals. Unfortunately, such micro data on variances are difficult to obtain.

Subsequent applications have shown that the risk aversion coefficient is unstable ; an outcome not predicted by the theory and which sheds doubt on whether the coefficient is fundamental parameter or an artifact.

The QP formulation has been criticized at a technical and at a theoretical level. At the theoretical level, some economists, notably Shackle (1949, 1961), have argued that maximizing expected utility is inherently irrational if the loss potential could destroy the firm or (what is in some ways analogous) if one is not guaranteed financing to "play the game" an indefinitely large number of times. This criticism led Boussard and Petit (1966) to develop a "focus loss" constraint approach. The rationale of this formulation derives from Shackle (1949, 1961) and Roy (1952). Formally, it replaces the expected income-variance (E-V) hypothesis of expected utility maximization. The alternative hypothesis is to maximize expected income subject to a constraint that the probability of ruinous losses should not exceed an (subjectively) arbitrary level. This formulation is consonant with the "chance-constrained" programming of Charnes and Cooper (1959). Thus the "focus-loss" (FL) approach involves a different behavioral hypothesis and also results in an LP rather than QP model. It is arguable that the difference in behavioral hypothesis is the more fundamental. If, of course both have the same observable implications, then algorithmic convenience is the more important difference.

Contemporaneously with Boussard's work, others were dissatisfied with QP not for its behavioral assumptions but because of the algorithmic weaknesses of QP vis a vis LP ; problems of size, algorithmic convergence, uniqueness etc. This concern led to the "Minimum Of the Absolute Deviations" (MOTAD) model of Hazell (1971). This formulation replaces variance components with the sum of absolute deviations. In fact, one of the criticisms of the QP formulations was that positive and negative deviations from the mean, are penalized equally. Such objections are implicit assertions that the first order approximation to expected utility is not a good approximation since it implies behaviour which is, a priori, implausible. The MOTAD model allows unequal (even opposing signs) weights on positive and negative deviations.

From a pragmatic point of view, does it matter whether one chooses an E-V/QP, MOTAD or an FL approach ? Surprinsingly enough, Boussard (1969, 1982) suggests that the answer is probably not. The reason is that all three involve risk aversion coefficients whose values are assigned by the analyst somewhat arbitrarilly. Given this degree of freedom, it is usually possible to obtain similar results form dissimilar models by adjusting the coefficients. One is reminded of early efforts to "solve" various problems in benefit-coast analysis through "appropriate choice" of the discount rate. For any given desired result there will exist a discount rate (perhaps negative or imaginary) which ratifies the desired result. One can achieved the same end result by juggling the price of steel, labor or concrete ; the coincidence of results does not necessarily commend the practice. In the choice between QP, MOTAD and FL approaches, one needs a wider range of empirical testing in which the

outcome is not known beforehand. A more persuasive theoretical case for one or the other would be helpful also. The most persuasive case would be by deriving testable behavioral implications which differ between the three.

The assumption of perfect markets is necessarily relaxed in varying degrees in applied research. In investigations of investment decisions, researchers have used the term "capital rationing" ; usually in conjunction with the adjectives "internal" and "external". The phrase is oxymoronic since all economic resources are rationed ; only the mechanisms differ. Rationing may be by price or non-price mechanisms. Thus, if the supply price of capital is convex with respect to the debt equity ratio, then optimal borrowing by a risk neutral borrower would involve the usual marginal conditions modified by the supply price flexibility of capital with respect to the debt equity ratio. Such price rationing cannot be judged by supply price and rate of return only. One must include the appropriate flexibility. This should not be termed internal capital rationing per se but it does reflect a market imperfection.

The term internal price rationing usually refers to non-price rationing mechanisms. These may be internally or externally imposed. In the case alluded to above, the market imperfection arises because of external capital rationing ; specifically, the lender conditions supply price on the debt equity ratio. At the risk of belaboring the obvious, it is not always clear what hypotheses are being tested when risk and market imperfections co-exist. This is further complicated when one introduces a dynamic structure . It is common to require loan repayment faster than the real rate of asset depreciation. For the borrower, such a policy provides security of collateral. For the lender, the excess is a forced savings. In optimizing over time, a borrower must take into account such repayment schedule rigidities. For internal capital sources, the timing of repayment is a matter of convenience not necessity. Such differences in the financial constraints for capital are no less real than purely technological constraints. The rigidities of repayment schedules also interact over time with minimum consumption flows. Consumption can, of course, be sustained by drawing on internal or external capital sources. In so doing, optimal decisions over time must reflect financial and consumption needs in all future time periods.

The financial and consumption flows mentioned above are independent of risk. If individuals behave "as if" they have safety rules, then repayment schedules and consumption needs will in some way require an acceptably small probability of ruinous cash flows. Such levels will probably be net worth dependent and therefore time dependent.

We need not restrict ourselves to internal capital (i(1)) and to secured loans (i(2)) with fixed repayment schedules. If one resorts to venture capital at opportunity cost (i(3)) then a necessary condition (constraint) for attracting venture capital VK(t) is that the present value of venture capital inputs must be less than the present value of the venture capitalists share of terminal net worth. In addition to this constraint (which can be linearized), we must treat the percent venture capital as a decision variable. One now has a bargaining situation in which the entrepreneur and the venture capitalist each wishes to maximize his respective share of terminal net worth. The solution

depends on the alternatives, bargaining power and aggressiveness of the two sides.

If we assume i(3) > i(2) > i(1), it may appear unlikely that one would use venture capital until the two lower cost sources have been exhausted. However, secured loans typically have rigid repayment requirements. If the marginal return from operating capital is high enough (greater than i(3)), it may be optimal to draw immediately on venture capital to avoid repayment requirements in early years. Later, as net cash flows become positive, one may then resort to lower cost secured loans since cash flows permit one to meet repayment obligations. Note also that venture capital changes the structure of the entrepreneurs risk ; only his share of net worth is at hazard. However, "ruin" is a knife-edged concept ; the entrepreneur and venture capitalist survive jointly or neither survive. Consequently, it is not clear that this change in financing would affect marginal rules of the operation of the entrepreneur.

A consequence of the preceding considerations is that optimal (in a behavioral sense) firm growth will depend, inter alia, on financial status, external loan policies and consumption/savings propensities. As a trivial application, consider the implications of indivisible costs. In a dynamic context, such costs, while not directly relevant to marginal conditions in production, are indirectly relevant because of their demands on cash flows over time and their effect on capital accumulation.

In the LP formulations of MOTAD and FL one can draw on the turnpike theorems of dynamic economic growth (Dorfman, Samuelson and Solow). In such models, the optimal trajectory tends (provided terminal time is "sufficiently" far away) toward a maximal or "turnpike" growth rate from time to to terminal time, T. It is to be expected however, that the introduction of risk aversion structures financial constraints and minimum consumption requirements will tend to affect this "turnpike". More specifically, firm growth will tend (by duality and Le Chatelier principle), to be lower than in a model in which these constraints are ineffective.

II - 2 Mathematical expression

In the flat oyster application, besides biological constraints which are of no interest here, financial and risk constraints are taken into account through specific rows :

- first of all, the enterprise is submitted to a fixed repayment schedule, forcing it to borrow more (if below the maximum borrowing capacity) to pay back its loans if no money is made available or to save more if the activity generate more than what is needed to pay for the existing loans ;

- secondly, we assume that one would enter the game only if he can afford for his own survival. In this aim, we build a maximum income constraint : below a certain level of income, even not very high, farmer

will leave to an other activity where he will be able to get, at least, this vital minimum ;

- finally, a focus loss constraint was set up to insure that the focus of loss in one year is less or equal to a certain fraction of the maximum loss permitted.

The linear programming model used is the conventional one in which the oyster farmer is assumed to choose, among various possible technologies (i.e how many numbers of hectares of each size class are grown or harvested each year, how many numbers of hectares are grown according to each growing technique) the combination which will yield the highest balance of savings (current external savings minus current external debt) subject to area, labor, natural productivity and capital constraints.

As the objective function, we choose to maximize the terminal value of assets, defined as the net worth as measured by loanable funds accumulated plus fish stocks by age class (evaluated at their in situ inputed value) less external debt balances. Actually, this objective function could be a misleading index if initial or terminal values of the assets/liabilities changed dramatically. A better index could be obtained in creating a new row called incremental wealth, by substracting initial wealth to the objective function.

The analysis previously developped can be expressed as follows : forgetting initial investments, closely tied with the dimension of the farm and supported by long term borrowing, operating costs need to be financed by short term loans (STBO) (less than 3 years). These loans may be either from equity capital or from external sources, differing by the interest rate charged, repayment schedules (equity loans need not to be repaid) and their effect on minimum consumption. By their demands for repayments, in future years, external loans also reduce the funds available to satisfy consumption needs in future years. Operating costs are classicaly linked to growing, harvesting and saling activities

$$COST(t) - \sum_{R=1} STBO(R,t) < 0$$

r=1 : equity capital
r=2 : external sources

The limit on short term borrowing derive from an other constraint on the current external debts. At initial time, external short term loans cannot exceed the initial borrowing capacity less external debt deriving from a previous activity and external savings at initial time. For other time periods, the constraint require that current external debt must be at least as great as the sum of compounded debt from the preceding period plus current external borrowing less current external loan repayments. A symetric constraint exists for current loanable funds.

The constraint on external loan repayment schedule should expressed that total repayments on external debt (SAV(2,t)) must be at least as great

as the current repayment obligations imposed by previous decisions. As a consequence, the rate of growth may be limited by the savings rate, a situation one can interprete as lender policies and external capital rationing :

$$eaf\ (i(2),D) * STBO(2,t-d) + SAV(2,t) > 0 \quad ; \quad t=1,T$$

D being maximum loan life and eaf the amortization factor for unit external loans

The minimum consumption constraint expresses that to stay in the game, oyster farmer has to get a minimum income from the activities. That is to say that the sum of net income -which is possibly non positive- and of net balance of borrowing and savings less the fixed cost should be at least as great as a minimum consumption level, MIN. In the application, MIN is set to an arbitrary level. The actual level should be determined by inquiries among oyster farmers, as a minimum sufficient to cover unavoidable expenses :

$$+ NET(t) + \sum_{l=1} (STBO(l,t)-SAV(l,t)) - FIXE > MIN \ ; \ t=1,T$$

Finally, the security constraint -the Schackle and Boussard's focus loss constraint- was defined as follow : let N(s,k,t) be a growing activity matrix and kappa an arbitrary risk aversion coefficient ; LOSS(t) is the aggregate loss, which must not be exceeded with probability greater than the level implied by kappa :

$$P(s,k) * N(s,k,t) - kappa * LOSS(t) < 0 \quad ; \ t = 1,T$$

This constraint implies that the focal loss on one growing activity (size s, technology k) cannot exceed a fraction kappa of the total loss, the variation of riskiness among growing activities being expressed in the P(s,k) focus loss coefficient. This specification involves S*K*T constraints and is one of the source of much of the model size. As we made the model a dynamic one, we allowed LOSS to be time variant. It is plausible that the level of losses deemed acceptable would increase (or decrease) with borrowing capacity or net worth. Thus, we add a constraint ensuring that the maximum potential loss may not exceed borrowing capacity less a non negative reserve, FUND2 :

$$LOSS(t) - BCAP(t) < FUND2 \quad ; \quad t = 1,T$$

Borrowing capacity, in turn, cannot exceed the sum of the cumulative loanable funds, and market value of assets BCO, discounted by a factor arbitrarily applied by the lending entities :

$$BCAP(t) < er * (CES(t) + BCO) \quad ; \quad t=1,T$$

BCO coefficients allows for non liquid assets which can be used as collateral. Those assets need not to be restricted to those peculiar to

the aquaculture plant. KNEZ et al (1985) in discussing various departures from expected utility maximization note that individuals differentiate among their assets in making risky decisions. Specifically, assets which are one's patrimony are regarded as "special" and individuals avoid to risk such assets. These points are of much interest in the application as we already mentionned that oyster farms are usually small family owned enterprises, were patrimony has been built over generations.

External capital rationing constraint express that current external debt cannot exceed external borrowing capacity. The lender's collateral or security for external loans is the sum of loanable funds and the salvage value of other assets :

$$CED(t) < BCAP(t) \quad ; \quad t = 1,T$$

It is assumed, as explained in the previous constraint, that external lenders discount the market value of assets by a coefficient er. For er < 1, the inequality will be strickly observed. However, for arbitrarily large variations in the risk aversion coefficient kappa, we expected solutions to switch from a risk averse solution of internal capital rationing to an apparently risk neutral one of external capital rationing. The model also allows to a reverse transition as capital accumulation increases borrowing capacity. The apparent risk aversion may then vary not only with individuals but mainly over time.

CONCLUSION

In order to take risk and uncertainty into account in a decision model we made two principal assumptions :

- farmers maximize their net income over a period of time under the constraint that the possibility is very small in any given year, of having an income below a minimum ;

- this constraint is fulfilled when, in Shackle and Boussard's terminology, the focus of loss of one production is less or equal to a fraction of the maximum loss permitted, defined as the level of loss farmers would find very surprising to reach.

Some limits of the model can be shown right now and we need to improve this model before drawing a correct supply representation :

- we only took into account incertainty on yield and prices because we assume that they are more important in oyster production. Other types nevertheless exist, as labor requirements and timeliness of operations, that may be crucial in using some technologies or when representing production at an etsvarine level ;

- in the model we built, we are not so close to the reality as we only allow choices in the sizes of harvested animals and technologies. Actually, oyster farmers do have more choice : they can choose the seeding size for instance ; they can also distribute their risks among different areas in the same basin or among various basins ;

- the results of an enterprise do not depend only on its own strategics. At the basin level, yield and prices depend on the total exploited area, on the competition with alternative uses of the share line, on the level of animal density (externalities) and on the production per unit of area. We plan to integrate those types of constraint to the previous model in order to increase it at a basin or regional level

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