THE POTENTIAL FOR INSURANCE TO MEDIATE ECONOMIC RISKS IN MARINE FISHERIES

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ABSTRACT

In agriculture there has been a long history of using a levy or an insurance premium to create mutual funds to mediate economic risks to growers due to environmental variability and quarantine pests. In the United States the federal government, through the USDA, continues to underwrite funds (collected by private insurance agents) which are used to protect contributors from the effects of extreme weather and pest and disease losses. In Europe mutual funds such as the *Kartoffelafgiftsfonden* in Denmark and *Potatopol* in the Netherlands have been developed to mediate risks from some potato diseases in different ways. This paper uses established methods of economic risk management from agriculture and applies these to marine fisheries to demonstrate how financial risks could be mediated by the creation of insurance funds. Through the use of probabilistic estimates of future catches and prices, and the risk of depletion across various scenarios, we investigate how government and industry participation in creating and managing funds may encourage increased protection of fisheries, and compliance and enforcement for fishery regulations. The paper also explores how fund exposure may be reduced by the application of reinsurance from commercial insurers for the upper tail of high cost, low probability events, such as total fishery collapse.

Keywords: capture fishery, insurance, risk, revenue, price, harvest, indemnity, premium

INTRODUCTION

Uncertainty affects the behavior of fishermen and fisheries regulators in a way that can negatively affect the sustainability of fish stocks and fisheries income and productivity. Faced with financial risks, fishermen might overexploit resources in the short term, thereby contributing to even greater financial uncertainties in the future. Insurance may provide a tool to address uncertainty in a way that would help fishermen and regulators achieve objectives of sustainability, income and productivity. However, the nature of fisheries risk may determine what forms of insurance are appropriate, and there are some constraints on the potential benefits from insurance.

Insurance mechanisms have long been used to mitigate financial risks presented by environmental and biosecurity uncertainties in agriculture. However, the sources of uncertainty that can adversely affect fisheries are manifold and often more difficult to define, predict and assess. Whereas the factors that affect agricultural outputs are often evident: the weather, pest infestations, disease outbreaks, etc, the question of what caused the decline in fisheries in most cases is impossible to answer with the same degree of confidence. Risks in agriculture are often heterogeneous over large areas, whereas fisheries risks may often apply to the whole stock. Many fish stocks are cyclical due to climatic and ecological factors, while others exhibit variability due to fluctuations in recruitment success, mortality, and migration. Continued exploitation can itself lead to greater variability in stock dynamics. An ever larger component of the risks to which the fishing industry is exposed comes from the socio-economic and political spheres via hard to predict and plan for prices, costs, labor availability and regulation.

The EC Framework 6 project PRONE, of which this work forms a part, is intended to address issues of risk in marine fisheries. A principal objective of the project is to adapt risk analysis theory and practice to European fisheries and to demonstrate a variety of tools to manage their risks. It also aims to develop improved risk management mechanisms that ensure that the outputs of risk assessments are catalogued and the management options available are adequately understood by stakeholders through effective risk communication.

Governments worldwide are heavily involved in regulating fisheries and yet few of these fisheries can be described as being both ecologically and economically sustainable. Insurance has proved a useful tool in mitigating risks and promoting sustainability in agriculture. This paper reviews the case for some applications of fisheries insurance and uses a stochastic simulation modelling approach to test the principles of an example insurance regime applied to a herring-like stock. Insurance may be a practical tool in some specific cases. Insurance has an advantage over many other options to reduce uncertainty because it can affect fishing behavior directly, and could provide quick feedback based on fishermen's immediate perceptions, while regulatory approaches rely on slow and often unreliable data.

The first part of the paper describes the initial results of the PRONE project analysis of using insurance to reduce risks in a modeled wild capture fishery by drawing on experiences in agriculture and contains an overview of the work of others in this field. The brief review is followed by a description of a framework in which an example insurance scheme is tested. The PRONE project is considering a full range of possible insurance schemes but in this paper only one is illustrated. The example not only demonstrates benefits of insurance but also some difficulties presented by an insurance scheme and how stochastic simulations may be used to identify potential solutions or limitations. Outputs of the insurance model are discussed and the direction of future work is presented.

REVIEW

In agriculture there are a number of examples of insurance being used to mediate financial risks to farmers. The Risk Management Agency (RMA) of the United States Department of Agriculture (USDA) provides insurance cover for over $67 billion of agricultural risk annually in the United States (up 60% since 2003), with more than one million voluntary subscribers growing over 100 insured commodities. The program offers a range of policy options to subscribers, who can insure against variation in price, yield or revenue, at a range of thresholds, with reference to either their own or local county average values over recent years. The indemnity is underwritten by the USDA and administered through a network of private insurance agents contracted to the RMA. The program has operated in a steadily evolving form since 1938. It constitutes a significant subsidy to American agriculture, but also requires as a condition of insurance that good agricultural practice is followed by farmers and requires that the regulator obtains good statistical information on risks and effectively manages public good actions [1].

In the Netherlands, an industry based agricultural insurance scheme has been used to mitigate financial risk caused by the specific risks posed by the introduction of two potato diseases new to the country: potato brown rot (PBR) and potato ring rot (PRR). For two years in the mid 1990s the government provided compensation for outbreaks of these diseases but drew the line after the second year of high outbreaks. Government continued to support research and regulation, which has contributed to a dramatic fall in PBR outbreaks and helped make the capped insurance scheme viable. The growers initiated the insurance scheme called *Potatopol* in 1997 [2,3]. *Potatopol* is an incorporated non-profit entity operated by potato growers and a small professional management staff. Government assisted the scheme with an initial grant of €250,000 to help establish the program. Growers pay an annual premium based on their potato area, potato market sector (seed, ware or starch) and coverage levels (standard cover or 30% +/- standard). Part of the contractual agreement is that if, in a bad year, there is particularly high demand on the fund then subscribers may be obliged to make an additional payment to the fund, with a fixed maximum. Recent levels of outbreaks have not required top-up payments, but growers know that their maximum exposure is limited [3]. If there is a particularly bad year and the fund, despite emergency premiums from subscribers, is still unable to cover the necessary outlay then *Potatopol* makes use of commercial reinsurance to ensure all indemnities are paid. Commercial reinsurance premiums are paid out of the annual subscriptions. The fund is capped at a predetermined level, commensurate with likely risk, and any excess money remaining in the fund at the end of the year is returned pro rata to the subscribers. Certain risk reducing activities are stipulated in the contract, including an undertaking not to irrigate with water declared infected with PBR and, following an outbreak, the soil must not be reused for potato growing for at least four years. Compensation payments are limited to the loss of crop in the year of an outbreak, and do not cover subsequent loss of use for potato growing. The scheme has been running since 1997, with approximately 95% of seed growers, 40% of ware growers, and 75% of starch growers participating.

Denmark also has had concerns about PBR and PRR. There is no government compensation available, but growers are supported through a fund (*Kartoffelafgiftsfonden*) set up by the Danish Potato Council (*Specialudvalget for Kartofler*) [2, 4]. The fund is administered by farmers, the Potato Council and government. Growers pay a compulsory levy of approximately €0.54 per tonne of potatoes sold, which is collected by the firms that buy potatoes. The fund raises about €540,000 a year on approximately one million tonnes of production. Compensation from the fund is set at 60% of costs faced by a grower due to an outbreak, but only covers costs (lost crop and destruction costs, but not replacement seed) borne in the initial year (as in the Netherlands *Potatopol* programme). By 2004, a group of insurance companies offered additional insurance to potato growers to cover the proportion of the loss from 60% up to 90% of the first year costs, and including the costs for buying new seed in the following year. The insurance costs €20 per hectare of potatoes, and 10% of potato farmers have taken out this insurance. The potato compensation fund also does not carry over unspent funds, but, unlike *Potatopol*, surpluses are invested in potato research carried out by public and private institutions competing for the funds. So far, the fund has not been depleted by claims in any year.

The rationale for the government support of insurance schemes in agriculture could also apply to fisheries. Insurance might promote sustainability in fisheries, encourage best practice, protect the industry and employment in the sector, and help ensure that ecological goals are met by designing insurance policies directed to such objectives.

Given the similarity of privately owned aquaculture to agriculture we should expect that insurance schemes would be applied to aquaculture before they are extended to wild capture fisheries and, indeed, insurance in aquaculture is already widespread [5]. Many fishing risks have, and continue to be, covered by insurance including vessel, gear and crew safety policies. However the application of insurance to catch, price and revenue variation is more problematic in wild fisheries, which explains the paucity of examples in the literature. The harvests of several specific marine fisheries are already covered in Japan by a government backed Mutual Insurance Scheme where their aim is to maintain a viable industry to secure production capacity. The scheme enables fishermen to share risks, shielding individual fishermen from ruin caused by natural disasters and other uncertainties. However, the distinguishing feature of these fisheries is that the species are, like aquaculture, geographically well defined and contained: such as kelp, sedentary shellfish, algae, etc [6]. The following section summarizes two important published studies concerning the application of insurance to genuinely wild capture, common resource, mobile fisheries; the first is a theoretical application of insurance theory by Donald Ludwig and the second is a more applied approach in which the USDA considered extending RMA crop insurance principles to wild Sockeye Salmon in Bristol Bay, Alaska.

Theoretical application of insurance to wild fisheries

In "A quantitative precautionary approach" Ludwig [7] begins with the premise that fisheries management needs to be precautionary, which is a fundamental assumption of the PRONE project as well. He builds on the idea that taxes and charges can be better instruments in achieving risk averse management of fisheries than direct regulations (such as TAC or effort control) by demonstrating the utility of insurance with some simple models. The insurance regime Ludwig considers is mandatory, as one of the objectives of an insurance regime as conceived by Ludwig, is to place an extra burden on the fishermen: in this context the fishermen are creating risks (of stock collapse) which are borne by the general public and requiring fishermen to purchase insurance would partly shift the risk burden back onto the generators of risk. Ludwig does not consider designing an insurance scheme according to the needs of the fishermen, but rather as a tool to neutralize the hazard that excessive fishing effort can be to an ecosystems. He claims that a bond or insurance regime can achieve several objectives. The key points are summarized in Table I.

Ludwig uses a stochastic surplus production model with three different harvest control rules: constant harvest rate, constant catch, and adjusting harvest rate based on abundance level in order to obtain a target catch. He claims that the main difficulties with setting up an insurance regime are political, institutional and philosophical and that sound actuarial calculations can be made for fisheries. He does not substantiate this last claim; however the Management Strategy Evaluation (MSE) approach would allow the equivalent of an actuarial basis, since management is based on modeled populations rather than real population attributes [8]. Thus, if response behavior of both fish stocks and fishing effort can be accurately modeled in the MSE approach, it would form a suitable foundation on which to add insurance as a management component.

Table I: Summary and Comments on Ludwig's Paper

Ludwig's points	Observations
Prevent risky exploitation by increasing the costs through premiums which are proportional to risks, hence rendering the most risky activities unprofitable.	Insurance may keep fishermen in business that otherwise would have been forced to leave.
Shift the risk burden from the public to the fishermen – "polluter pays principle".	Punitive insurance premiums, as envisioned by Ludwig, will not necessarily lead to greater social fairness. It is not always possible to determine who within an industry is causing the loss, or how much, so everyone in the industry pays, even if they do not cause loss.
A clear link between a harvesting strategy and a premium would alter the behaviour of the fishermen and make them less likely to cause harm to the stocks and the ecosystem.	In theory, modeling approaches such as risk assessments or management strategy evaluations can be useful in linking the size of premiums to harvesting strategies. But the potential effectiveness of insurance to influence behavior of fishermen is unknown. The difficulties of monitoring activities at sea could make fisheries insurance less effective than agricultural insurance at lowering risks through its influence on individual behavior.
The assessment of risk depends on the state of knowledge, so charging for risk would provide financial incentives for industry sponsored research.	Knowledge, particularly the ability to predict future harvest, creates a problem for insurance by enabling fishermen to "fish" the insurance by purchasing the cover in anticipation of payouts. On the other hand, there is no guarantee that obtainable knowledge would be useful enough to reduce insurance premiums. A final case, in theory, could be that information would obviate the need for insurance by effectively eliminating risk.

Sockeye Salmon Case Study

In 2001 the RMA of the USDA contracted the University of Alaska Fairbanks Agricultural and Forestry Experiment Station to scope a pilot crop insurance program for the Bristol Bay commercial salmon fishery [9]. It represents the first attempt to extend USDA crop insurance to wild fisheries. The draft report concluded that until the fishery reaches stability, it would be difficult to design and administer an insurance policy that would benefit the industry. As a result an insurance program was not set up. However, the initial design phase identified many practical issues regarding guarantees, insurance triggers and indemnity payouts that are relevant to the design of potential insurance schemes in other wild fisheries.

The Salmon study draws some important differences between risk factors and insurance schemes in agriculture and wild fisheries. The RMA identifies three important components for crop insurance, namely peril, moral hazard and adverse selection:

- In agriculture, peril is defined as unanticipated/unavoidable events that affect some outcome, such as low yields caused by bad weather, fire, and uncontrollable pest losses, etc. In fisheries, the definition of peril needs to be modified since it is difficult, perhaps impossible, to develop a sound actuarial basis to determine the contributory effect of natural events to catches in any given year. For this reason the authors suggested that peril in wild fisheries should be redefined as an outcome: low catches or low fishery exvessel revenues rather than identifiable causes.
- Avoiding moral hazard, defined by the RMA as an action taken by producers to maximize return from the insurance product by limiting their production of the insured crop, requires good risk insurance design to avoid incentives for harvesters to "fish" the insurance. Good design would likewise ensure that insurers were able to differentiate between legitimate and illegitimate claims and, conversely, prevent insurers from rejecting legitimate claims. A marine fishery equivalent to "best agricultural practice" was not easy to define, which would make it difficult for loss adjusters to identify causes and weights of contributing factors. For these reasons, individual performance based guarantees were rejected and various group based catch-per-effort triggers were simulated in their deterministic catch and price history insurance simulations.
- The third RMA component, adverse selection against the insurance provider, occurs when the insured person has better knowledge of the relative risk of a particular situation than does the insurance provider. In fisheries, harvests are dependent on biological phenomena. In the Salmon case-study, run strength over time may be correlated with previous events and thus, to some extent, could be predictable. Fishermen may be able to

predict insurable events in years when poor runs were expected which would be a severe compromise to a sound risk insurance program. A multiple year obligation to subscribe to the insurance product was suggested as a possible solution.

Unlike in crop insurance, the insurable units in fisheries are rarely homogeneous: fishing opportunities do not determine individual performance. For this reason the report suggested that indemnity payouts should be paid based on Average Performance Histories (APH) of individual fishermen within the fleet so that, in poor years, they would be compensated commensurately with their fishing performance in previous years, assuming similar effort was demonstrated.

The sockeye salmon fishery in Alaska was suffering from poor prices at the time of the study as a result of other salmon species gaining favor in the Japanese market. As a result the Bristol Bay fishermen desired revenue based triggers so they would be covered for poor catches and/or lower prices.

The report raised the concern that insurance could interfere with the effort to reduce capacity in the fishery by essentially subsidizing fishermen that would otherwise leave either permanently or temporarily.

MODELLING METHODS

Model structure

A stochastic population dynamics model of a herring-like stock was developed to illustrate how the economic stability of a fishery can be affected by an insurance regime. This model allows us to explore, quantitatively, the links between risks introduced through either environmental, or knowledge related, uncertainties versus risk introduced through implementation of fisheries management, and the scale of insurance premium required to mediate the risk.

The insurance policies modeled here are based on systems employed in agricultural risk management, such as the RMA of USDA. Harvest shortfalls are covered at selected price levels. Indemnity payments are triggered when the harvest falls below the covered proportion of an historical average harvest (for example, the previous ten years). The size of an insurance payment depends on an agreed price coverage level, modeled as a proportion of the preceding average price.

We calculate the size of a premium needed to guarantee that the insurance fund is sufficient to cover losses after the first 10 years of operations in 75% of the simulations. The most extreme 25% of the simulations are assumed to be covered by reinsurance; a premium charged for re-insurance is calculated separately. During the first 10 years of operation the fund is allowed to borrow money at 8% interest. Insurance funds can earn 5% annual interest when not used to make payments. The introduction of reinsurance to the model deviates from the Salmon insurance example and simulates the *Potatopol* use of reinsurance to limit fund exposure to high cost/low probability events.

The model is stochastic and the variability of its predictions can be controlled by changing the standard deviation of the parameters representing biological or fishermen's behavior-related uncertainty. The model is designed to explore ideas related to insurance, building on the theoretical framework suggested by Ludwig [7]. We use an age-structured model, with a stochastic stock-recruitment Beverton and Holt type relationship. Prices are considered elastic with respect to the supply of fish [10]. The parameters of the stock-recruitment relationship are based on Bayesian hierarchical meta-analysis of the herring stocks [11]. Other parameter values, such as maturity, mortality and weights at age are based on ICES stock assessments.

Population model description

The model is implemented in R using three-dimensional arrays storing numbers of herring in billions by age, year and simulation. Before beginning the insurance regime we assume that the stock has been exploited similarly for 100 years to establish a historical record of population trends. The harvest is assumed to occur in the beginning of the modeled year, and spawning in the middle, the age of recruitment is taken to be 1:

$$C_{a,y,s} = N_{a,y,s} * H_{a,y,s}, \qquad \text{(Eq. 1)}$$

where C stands for catch (in billions of fish), N for number of herring (in billions of fish), and H for harvest rate;

$$Y_{y,s} = \sum_a C_{a,y,s} * W_{a,y,s}, \qquad \text{(Eq. 2)}$$

Yield is given in millions of tonnes, where W is the weight (kg) of individual fish at age;

$$N_{a+\Delta t,y+\Delta t,s} = (N_{a,y,s} - C_{a,y,s})\exp(-M_{a,y,s} * \Delta t), \qquad \text{(Eq. 3)}$$

where Δt is equal to ½ or half a year and M is an instantaneous natural mortality rate;

$$SSB_{y,s} = \sum_a \left(N_{a+\Delta t,y+\Delta t,s} * Mat_{a,y,s} * W_{a,y,s}\right), \qquad \text{(Eq. 4)}$$

spawning stock biomass (in millions of tonnes) is denoted by SSB, Mat stands for proportion of sexually mature herring by age;

$$N_{1,y+1,s} = \frac{\alpha_s * SSB_{y,s}}{\beta_s + SSB_{y,s}} * \varepsilon_{y,s}, \qquad \text{(Eq. 5)}$$

the above stochastic stock recruitment relationship gives the number of age 1 herring for the following year, where alpha and beta are Beverton and Holt recruitment function parameters and epsilon is a log-normally distributed process error with specified precision (Fig. 1). Population dynamics of herring (and fish in general) is largely driven by the variability in recruitment success from year to year. The parameters of the stock recruitment function are based on the estimates of the recruitment relationship for the Norwegian Spring Spawning herring; the recruitment time series for Norwegian Spring Spawning herring for the last 57 years are included in the figure below displaying a random modeled trajectory for a herring-like stock over a sample period of the same length.

For the older groups, transition from year to year is modeled by:

$$N_{a+1,y+1,s} = N_{a+\Delta t,y+\Delta t,s}\exp(-M_{a,y,s} * \Delta t) \qquad \text{(Eq. 6)}$$

We assume that prices are influenced by the amount of supply (catch) and the price flexibility coefficient is taken to be -0.25 [10]:

$$P_{a,y,s} = P_a * \left(\frac{Y_{y,s}}{mean(Y_{y,s})}\right)^{-0.25}, \qquad \text{(Eq. 7)}$$

where P stands for price. For insurance calculations we use average price per kg of catch, rather than an age specific price:

$$P_{y,s} = \frac{\sum_a P_{a,y,s} * N_{a,y,s} * W_{a,y,s}}{Y_{y,s}}. \quad \text{(Eq. 8)}$$

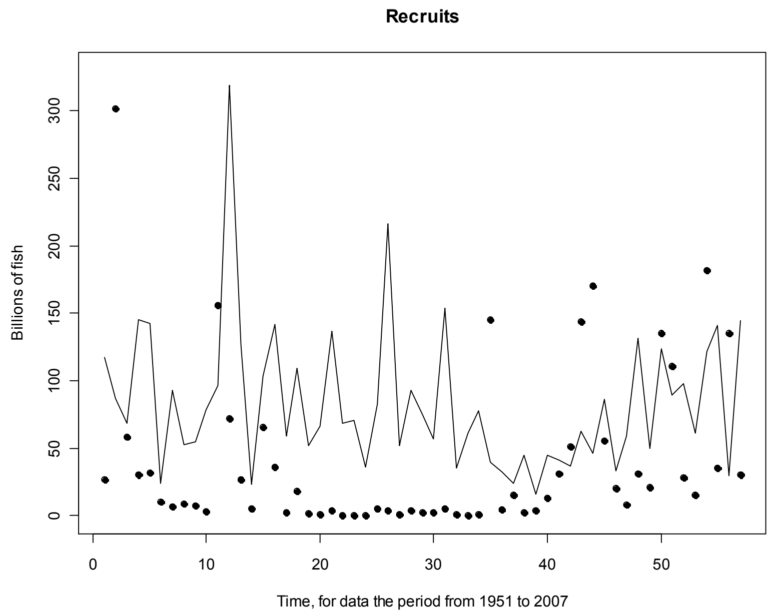


Figure 1. The line represents a random recruitment trajectory alongside the estimated recruitment time-series for the Norwegian spring spawning stock for 1951 to 2007 (data are shown as points)

For the purposes of illustrating the functioning of the insurance regime, we simulate 1000 iterations over 30 years for each scenario. For this time period, we calculate the size of the insurance payouts for 80% harvest, 100% price coverage policy; that is, compensation would be triggered if catch falls below 80% of average and price below 100% of average. We use the same format for a range of price and harvest thresholds of 60%, 80% and 100% of the rolling 5 year average for price and harvest.

First, for each year and iteration we calculate the average yield for the preceding five years:

$$\overline{Y}_{y,s} = mean(Y_{y-6,s},...,Y_{y-1,s}). \quad \text{(Eq. 9)}$$

The trigger, $T_{y,s}$, for insurance payment is based on the average yield, $\overline{Y}_{y,s}$, and on the coverage level selected, which we assume for now is 80%:

$$T_{y,s} = 80\% * \overline{Y}_{y,s}.. \quad \text{(Eq. 10)}$$

If the simulated harvest $Y_{y,s}$ is below $T_{y,s}$, then an insurance payment $IP_{y,s}$ is made of the size depending on the price coverage level specified in the insurance plan (here 100%) and the average of price per kg over the last five years:

$$IP_{y,s} = (T_{y,s} - Y_{y,s}) * 100\% * mean(P_{y-5,s},...,P_{y-1,s}). \quad \text{(Eq. 11)}$$

To calculate the premium we use a search algorithm that finds the minimum premium required such that the insurance fund raised is sufficient to cover up to the 75th percentile value of the annual payouts over all the simulated scenarios. The insurance fund is capped, so that the annual premium payments are suspended while the fund is at its capped value, and the interest earned is returned to policy holders on an annual basis. This is referred to as the mutual fund. During the first 10 years the fund is allowed to borrow money if needed at 8% interest, conversely the money not used for payouts is invested at 5% annual rate of interest (Fig. 2). The operating costs are assumed to add 10% to the total collected premium for the mutual fund.

The upper 25% of liability is covered by commercial re-insurance bought in the market. The premium for re-insurance, Ψ, is calculated by adding a 25% profit margin to the expected annual re-insurance payouts ($reIP_{y,s}$, total payout less the re-insurance threshold level at the 75th percentile of annual payouts) in the extreme 25% of the simulations:

$$\Psi = \underset{s}{mean}\left(\underset{y}{mean}(reIP_{y,s})\right)*1.25 \qquad \text{(Eq. 12)}$$

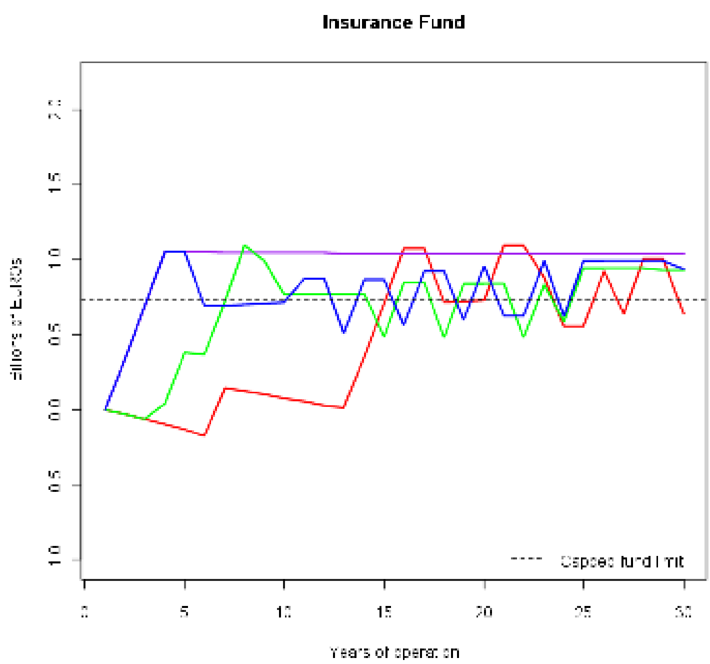


Figure 2. Building an insurance fund over 30 years in four simulated scenarios, this example assumes 100% coverage level for both price and harvest; note that the fund sometimes exceeds the fund cap because of the fixed premium level

RESULTS

The size of the insurance payout and the corresponding premiums are dependent on the details of the policy chosen. The table below describes the results of calculation of premiums and reinsurance premiums under different combinations of price and harvest coverage levels (CL) assuming the same population dynamics in each scenario. For these calculations, insurance payouts are based on the harvest and price averaged over the 5 preceding years (Table II). The average annual revenue in the simulations is €1.74 billion, thus insurance payments depending on the policy, constitute 0.4% to 14.1% of the average annual revenue (Table II).

Table III shows fund caps for the mutual fund at various coverage levels note that, because only very low insurance payouts were required, the fund cap for the 60% harvest coverage level is very small.

Table II: Total Annual Insurance Premiums for Different Levels of Catch and Price Coverage

Total Expected Annual Premium plus Total Reinsurance Premium in € billions/year (and as a % of average annual revenue)	60% Price CL	80% Price CL	100% Price CL
60% Harvest CL	0.006 (0.4%)	0.009 (0.5%)	0.011 (0.6%)
80% Harvest CL	0.051 (2.9%)	0.068 (3.9%)	0.085 (4.9%)
100% Harvest CL	0.148 (8.5%)	0.197 (11.3%)	0.246 (14.1%)

Table III: Calculated Fund Caps for the Mutual Fund at Various Coverage Levels

Calculated caps for mutual fund at different coverage levels (€ billion)	60% Price CL	80% Price CL	100% Price CL
60% Harvest CL	0.000	0.000	0.000
80% Harvest CL	0.027	0.036	0.054
100% Harvest CL	0.439	0.585	0.731

DISCUSSION

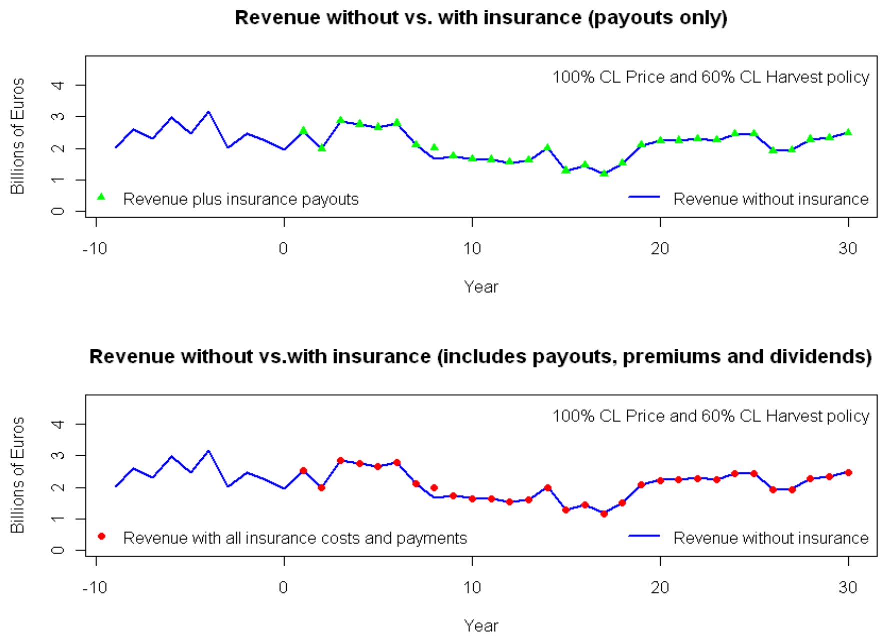
The size of the payouts and therefore the premiums is influenced by all the factors that contribute to the variability in predictions. We can use the model to explore how changing the assumptions regarding the variability of model parameters could affect insurance. This is useful because certain sources of uncertainty are indeed controllable: knowledge can be improved, reducing uncertainty in the estimates of model parameters; fishing can be controlled so as to reduce both the level of exploitation and the variability of harvest rates. We can use the model to investigate the benefits of reducing the controllable sources of uncertainty measured by the lowered cost of insurance.

The focus of an insurance tool varies between fishing industry and fisheries regulators. For industry the focus is on revenue (a product of catch and price) set against individual or fleet average records and effort employed. A variety of fund creation and management options are available including: fixed premium, variable fund; variable premium, fixed fund; invest or return surplus in fund, at various intervals; frequency of premium or fund review; capped or uncapped liabilities; reinsure upper tail of liability, or leave unmet, etc. Our example model has been developed for a fixed on/off premium variable fund with capped liabilities (enabled by the use of reinsurance) but any system could be simulated and their impacts evaluated. The model demonstrates how insurance payouts can provide a "soft landing" when there are short, sharp declines in harvest (such as in Fig 3b, years 7-9), giving a few years for longer term adjustment. Where there is a long term decline in harvest insurance is not likely to be able to help (Fig 4). The level of insurance is important in determining the effect on subscribers; in Fig 3a a 60% harvest threshold does not trigger payouts, an 80% threshold holds net revenue level for a few years as harvests fall (Fig 3b), while a 100% harvest threshold (Fig 3c) results in "over-compensation" for several years, which may send the wrong signal to fishermen. Lower thresholds than those in Fig 4 do not trigger insurance payouts in steadily declining harvests, as the average reference base falls at a continuous rate. In these conditions progressively smaller catches coupled with continued premium payments feeding a growing fund would make an insurance scheme highly unpopular. This suggests that other forms of fund creation and management shoud be evaluated in future models, such as a continuously variable annual premium reassessed each year, or a constant, fixed premium.

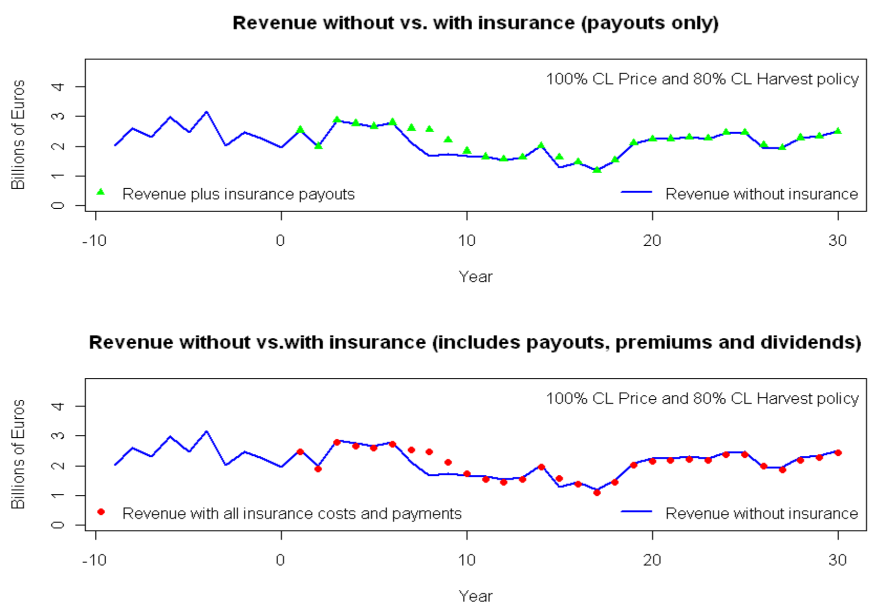
The focus of regulators tends to be towards increasing sustainability of exploitation and thus production. It is likely that the primary requirement of an insurance instrument would also depend upon increasing sustainability of production rather than protecting revenues. This could be built into an MSE modelling approach to test fisheries management actions. In Figs 3 and 4 the different pairs of graphs demonstrate the potential role of subsidy if government bears the cost of insurance subscriptions, which could also give more control to regulators.

The insurance model developed here is purely reactive and acts like the Salmon insurance example in which the sole purpose is to iron out the lows of revenue for the fishers. This insurance scheme is not dynamic with respect to the stock, so the catch affects the insurance payout but the insurance is not directly tied to biological markers or stock management actions and it does nothing to prevent poor catches or reduce risk in catch size in subsequent years. Ongoing work will develop a more sophisticated approach where a simulated fishery model can make predictions about the Total Allowable Catch (TAC) for the coming season and the fleet will subscribe to that TAC enforced at different levels. Should the TAC fall below 60, 80 or 100% (depending on coverage bought) of some average of catches over previous years then a pay-out would be triggered that makes up the difference. In this case insurance is assisting the fleet to comply with the TAC which may, without insurance, have caused hardship. This latter system more closely resembles Ludwig's proposal [7] and is more prospective than the current model since it reduces financial risk to fishers each year while satisfying regulators by dampening catch risks from overfishing in future.

a)



b)



c)

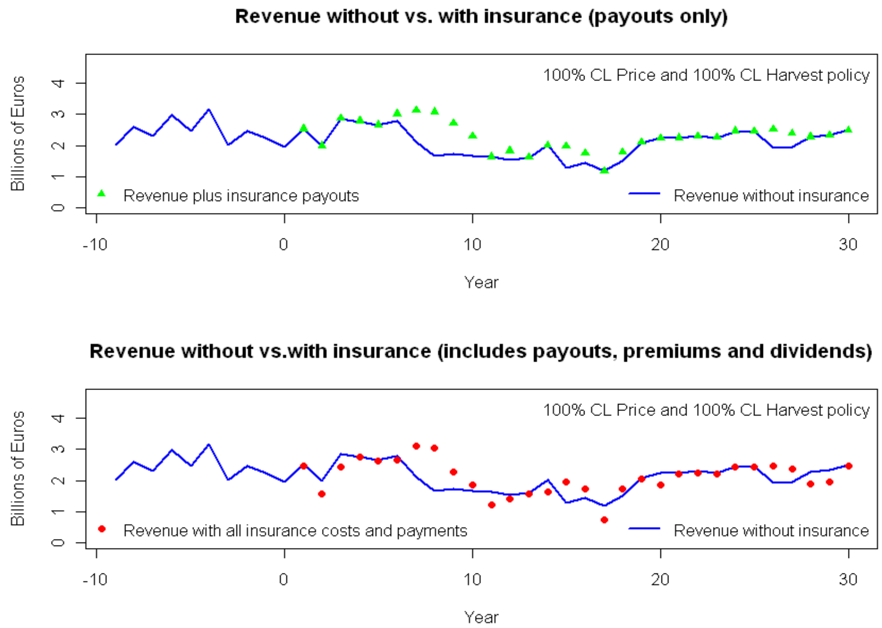


Figure 3. Revenue with and without insurance policies (100% price and three levels of harvest coverage levels (a) 60%; b) 80%; c) 100%) based on 5 year averages

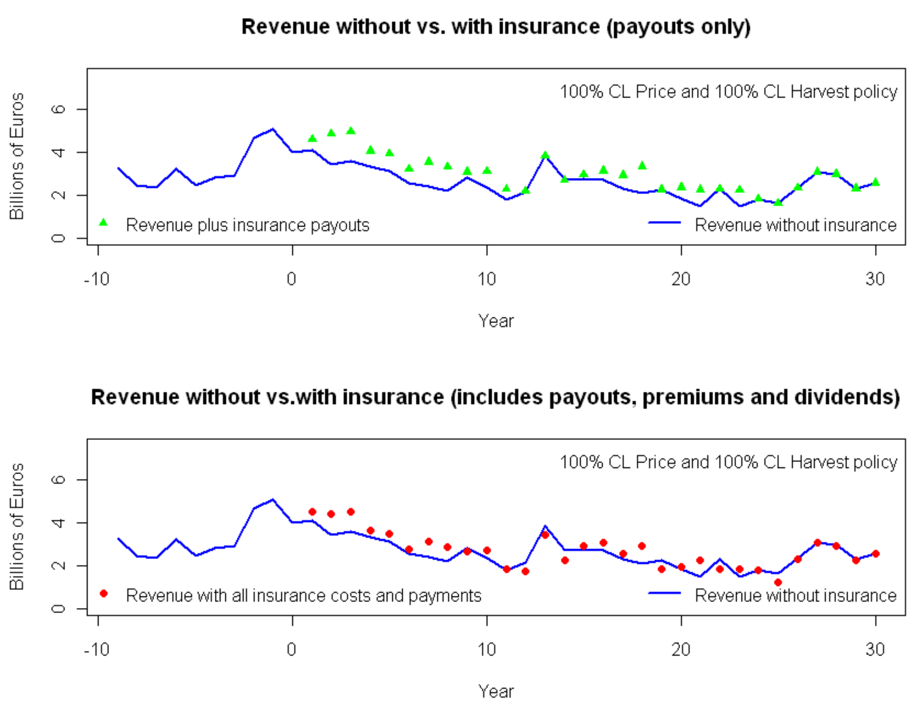


Figure 4. Revenue with and without insurance policy (100% price and 100% harvest coverage levels)

The Common Fisheries Policy (CFP) is a potential setting for a Europe-wide insurance regime. If all stocks were insured in Europe, then at least in a future when structural reforms have taken place and fleet overcapacity is eliminated, a universal insurance scheme could be justified. It might make sense to set up a single-crop insurance scheme in agriculture, with discrete homogenous units, but insuring a single fish species may not work where fishermen catch more than one species. Furthermore, it could be expensive, since in a single species fishery risks cannot be spread except over time. The conditions needed for the introduction of insurance should be determined, such as the impact of an insurance system on levels of stock health, as in the STECF HCR evaluation. This paper demonstrates the potential application of insurance in fisheries, but shows that there are significant issues related to the threshold values that trigger payouts, the level at which funds are capped, and whether premiums are constant, variable or fixed.

CONCLUSIONS

Insurance has three values:

- Reduces intrinsic unmanageable variance, which is worth a premium to subscribers (such as in hail insurance)
- Reduces risk behavior by subscribers, so can alter outcome variance or mean or both (contract compliance like crop hygiene, or good agricultural practice)
- Increases enforcement or control by regulators (either as a direct party to insurance as an underwriter, like RMA; or indirectly, like political pressure on flood control authorities from subscribers facing high insurance costs)

Fishing is well suited to insurance, since it has fairly high intrinsic variance in outcomes, a propensity to risk inducing behavior by fishermen, and a history of ineffective regulation.

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