# THE DYNAMICS OF A FISHERY WHEN FACED WITH THE AQUACULTURE DILEMMA

Andreea L. Cojocaru

Supervisor: **Frank Asche**

University of Stavanger

**uis.no**

7/21/2016

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# Background

- Aquaculture has been the world's fastest growing food production technology during the last three decades

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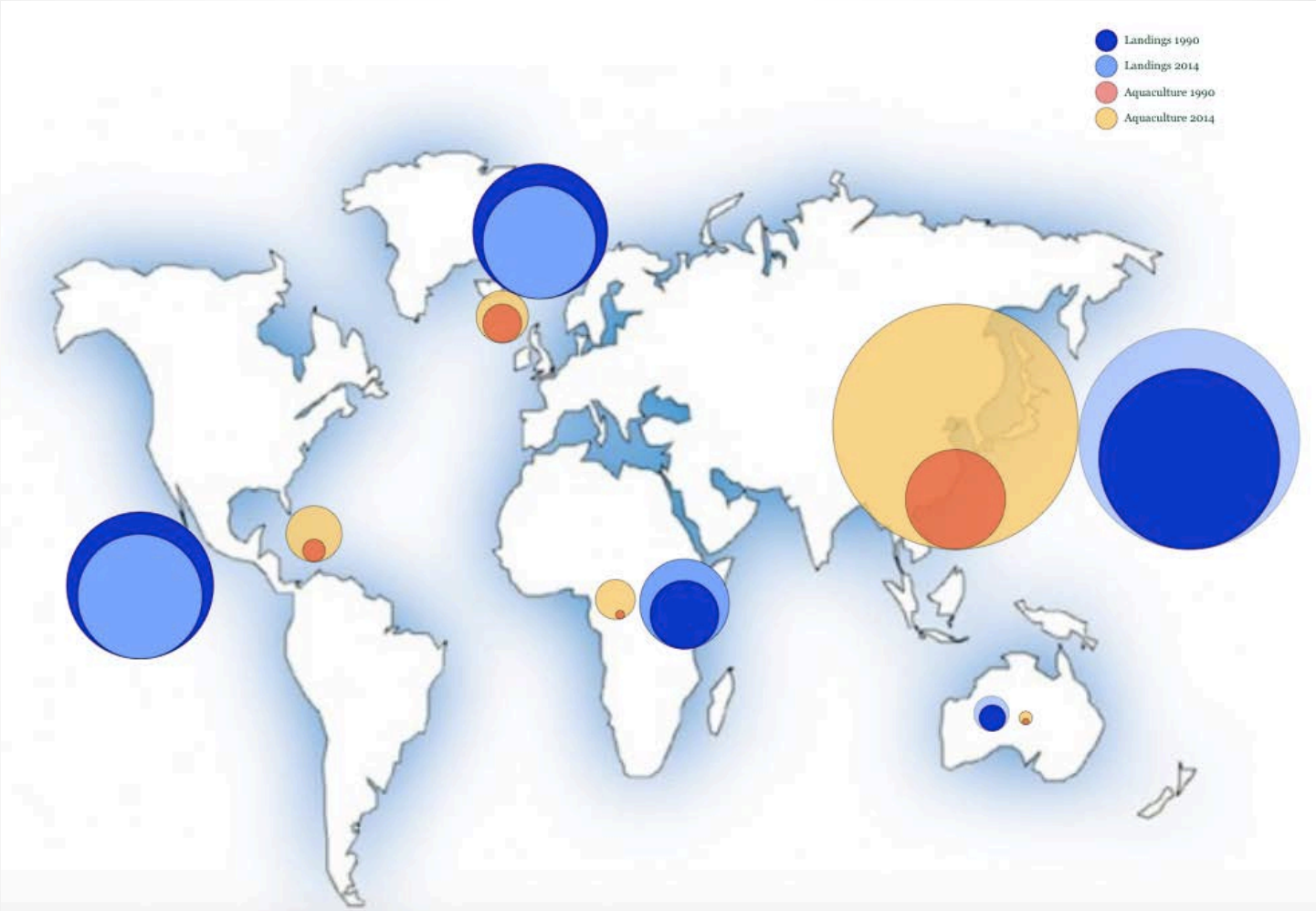


Source: FAO

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# Background

- Aquaculture has been the world's fastest growing food production technology during the last three decades
- The effects of aquaculture developments on the fishing industry remain to be thoroughly investigated
- We hypothesize that fishermen worldwide will face an additional challenge in their choice to reduce participation, exit or transfer from the fishery altogether, and how often and to what extent to invest

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# Literature

- Discovery of productive fishing grounds and development of fishing capacity
  - Open-access (Hardin, 1968; Clark, 1990)
  - Regulated open-access (Munro and Scott, 1985; Homans and Wilen, 1997)
  - Rights-based management (Arnason, 1990; Grafton, 1996)
- Understanding fishermen behavior
  - Risk level (Smith and Wilen, 2005)
  - To fish or not (Smith et al., 2010)
  - Target species (Zhang and Smith, 2011)
  - Relation to by-catch (Abbott and Wilen, 2011)
  - Gear choice (Eggert and Tveterås, 2004)

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# Literature

- Effects from an expanding aquaculture sector
  - Market interactions under perfect competition and monopoly (Anderson, 1985)
  - Aquaculture is expected to attract an increase in market share in its favor and away from fisheries (Asche et al., 2001)
  - Ecological effects onto fisheries (Hoagland, Jin and Kite-Powell, 2003; Mikkelsen, 2007)
  - Fish prices overall are lower due to aquaculture (Peridy, Guillotreau and Bernard, 2000)
  - Lower wages for fishermen that target close substitutes to established aquaculture species (Valderrama and Anderson, 2010; Asche, Bremnes and Wessells, 1999)

# Research Question

- Will aquaculture drive out commercial fishermen/fishing fleets?

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# Research Approach

- This study attempts to build a continuous-time model that links fishing fleet dynamics and renewable resource dynamics to determine the optimal equilibrium

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# Research Approach

- This study attempts to build a continuous-time model that links fishing fleet dynamics and renewable resource dynamics to determine the optimal equilibrium

- … with some aquaculture complications

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# Considerations

- Capital malleability
- Labor transferability
- Time horizon

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# Theoretical Model

- Restrict attention to a bio-economic model of the commercial fishery under sole ownership
- The biological basis for the model is a general production model developed by Schaefer
- The economic basis follows work by Gordon

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# Theoretical Model

- The resource stock model is based on the Pearl-Verhulst equation of population dynamics:

$$\dot{x}(t) = F(x) - h(t)$$

$$= rx(t)\left(1 - \frac{x(t)}{K}\right) - h(t)$$

$$= rx(t)\left(1 - \frac{x(t)}{K}\right) - qE(t)x(t), \quad x(0) = x_0$$

$$F(x) > 0, \quad F(0) = F(K) = 0, \quad F''(x) < 0 \ for \ 0 < x < K$$

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# Theoretical Model 1

- The effort, *E(t)*, highly correlated with the capacity of the fleet, *κ(t)*, such that:

$$0 \leq E(t) \leq \kappa(t), \quad E(t) = \phi\kappa(t), \ \phi \in [0,1]$$

- There is no constancy to fleet capacity:
  - New boats may be invested in to enter the fishery, or
  - Existing boats may be upgraded

  ⇒These are capital investments (Smith, 1968; Rinaldi and Walters, 1975; Clark, 1990), assumed to be correlated with profitability, and hence market price level

  ⇒Sufficiently high prices will encourage innovation and capital investments

  ⇒More technologically advanced fleets imply decreased harvesting effort

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# Theoretical Model 1

- $\kappa(t)$, is the amount of capital invested in the fishery at time $t$:

$$\dot{\kappa}(t) = I(t) - \gamma\kappa(t), \quad \kappa(0) = \kappa_0$$

Where $I(t)$ is the gross investment rate in additional capacity, and $\gamma$ is the rate of capital depreciation

- We assume, to begin with, that once an investment has been made, it can no longer be reversed, $I(t) \geq 0$ (i.e. no disinvestment)

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# Theoretical Model 2

- The effort, *E(t)*, highly correlated with the labor power, *L(t)*, such that:

$$0 \leq E(t) \leq L(t), \quad E(t) = \phi L(t), \ \phi \in [0,1]$$

- Arguably, capital will remain, while the necessary labor force may diminish to allow for automatization

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# Theoretical Model 2

- Fishermen may exit the fishery due to:
  - Mortality, or
  - To pursue other opportunities as a result of aquaculture's impact on fish prices, taking into consideration the degree of substitutability

$$\dot{L}(t) = I(t) - (m + \alpha(t))L(t), \quad L(0) = L_0$$

where $m>0$ is a constant denoting "natural mortality", while the exits due to aquaculture, $a(t)\geq 0$, will likely depend on the market price of the fish, and $I(t)$ stands for new recruitment

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# Theoretical Model

- The goal is to find the optimal *E(t)* and *I(t)* that maximize the objective:

$$\max \int_0^{\infty} e^{-\delta t} \{p_{wild} h(t) - cE(t) - \pi I(t)\} dt$$

- Price received for the fish is in part dictated by the aquaculture of the closest species
  - We assume that wild-caught fish will always be sold at a premium compared to their farmed cousins

$$p_{wild} = \frac{1}{\omega_{ij}} p_{aquaculture} + e, \quad 0 < \omega_{ij} \leq 1$$

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# Conclusions

- Aquaculture has been acquiring a competitive advantage over commercial fisheries in the long run, especially for closely related species (Jensen, Nielsen and Nielsen, 2014)
- New movements toward underutilized fish species, such as “dock-to-dish”
- Consumers may rationally choose to avoid “inferior seafood”(i.e. wild-caught fish in bad waters) in the future

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# Conclusions

- Proposed model, although theoretical in nature will:
  - Help provide insight into what is happening with fishermen in current fisheries
  - Create a basis of understanding for managers and policy makers to make proactive decisions

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# Questions and Suggestions?

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# Initial Model Assumptions

- Assumptions:
  - Sole-owner presiding over the fish population and owning full rights to its exploitation
  - A one-to-one relation between the sole-owner and the fishery, with the fish population uniformly distributed in space
  - No congestion of fishing boats on the water
  - No saturation limit for fishing gear used
  - Fishermen are assumed to have a pre-selected vessel and gear, but fishing effort can vary
  - The catch rates for the various vessels do not influence one another