

Cournot Oligopoly in Commercial Fisheries

Robert Deal

Abstract

This paper analyzes commercial fisheries through the lens of a Cournot oligopoly model to explain persistent overfishing under open access conditions. This paper models fishers as profit-maximizing firms that compete for harvest quantities, resulting in the exploitation of a shared, renewable fish stock. The examination finds that while firms internalize price effects, they often ignore stock externalities that result in aggregate harvest levels that surpass the social optimum. As the number of firms increases, conversely, total catch grows monotonically. This leads to accelerated stock depletion and the dissipation of resource rents. Incorporating biological stock dynamics, works to reveal that Cournot equilibria are not only inefficient but can be ecologically unstable, which increases the risk of long-run fishery collapse. Free entry further worsens the outcome, effectively by driving profits to zero while increasing total effort. This paper finds that through institutional interventions, specifically individual transferable quotas (ITQs) and limited entry movements, effectively work to internalize externalities, change firms' best response functions, and move equilibria toward sustainable harvest levels and higher long-run welfare.

Introduction

Within commercial fisheries, there exist many fishers who, through an economic lens, operate as firms that harvest from a shared renewable stock. When numerous firms supply a homogeneous product and have a hold of influence over market outcomes, the industry can be described as an oligopoly, which is defined as a market structure with a small number of independent firms whose actions affect one another (Tirole 1988). A standard model of an oligopoly is the Cournot model, which was introduced by Antoine Augustin Cournot (1838). This model is characterised by firms competing by simultaneously choosing output quantities while considering that the market price is dependent on total industry output. In this system, each firm treats rivals' quantities as a given when it decides on maximizing profit strategies.

A Cournot equilibrium could be described as the set of output levels at which each firm's selected quantity is deemed a best response to the quantities selected by every other firm. Formally, no firm can increase its profit through unilateral deviation (Fudenberg and Tirole 1991). In fisheries, this system displays strategic quantity competition among harvesters who exploit a common-pool resource. The economic issue arises due to fish stocks being non-excludable and rival in consumption; this creates what Hardin (1968) termed the "tragedy of the commons." Individual firms choose to maximize profit but ignore stock externalities, the effect on present harvest on stock availability in the future, and the cost for others (Gordon 1954; Clark 1990). This apparent divergence between both private and social incentives often leads to excessive aggregate harvest relative to the socially optimal level. Under open access, entry is allowed to continue until economic resource rents return to above opportunity costs, which is derived from the scarcity value of fish stock that is eliminated (Gordon 1964). This procedure, in which competition decays these scarcity returns are known as rent dissipation (Scott 1965). Within equilibrium, profits approach zero not due to an efficient outcome, but because excessive levels of effort and reduced stock levels work to absorb the resource's value. In turn, modelling fisheries as a Cournot oligopoly gives way to a structured way to formalise strategic interdependence, quantity competition, and rent dissipation. Through comparing the Cournot equilibrium to the socially optimal benchmark, light is shed on how decentralized profit maximization can lead to inefficient resource use and prolonged overfishing.

Literature Review

This economic examination of fisheries originates with Gordon (1954), who demonstrated that open access exploration of a common pool resource can lead to excessive entry and rent dissipation. Scott (1955) extended his framework through the comparison of open access to sole ownership, by showing that coordinated management could preserve resource rents. Hardin (1968) gave a wider conceptual basis through the "tragedy of the commons," explaining how, on an individual basis, rational behaviour could generate collectively inefficient outcomes.

Clark (1990) would later formalize fisheries within a dynamic bioeconomic system. He linked biological growth functions to intertemporal profit maximization; in addition, he demonstrated conditions under which optimal harvesting pathways could diverge from competitive outcomes. These models

worked to highlight stock externalities and the intertemporal trade-offs important to renewable resource management.

Within industrial organization theory, Cournot ([1838] 1897) introduced the model of quantity competition within static interdependence. Which was later formalised within newer game theory by Fudenberg and Tirole (1991). Tirole (1988) would further clarify oligopolistic behaviour and equilibrium concepts. He would do so through the application of Cournot competition to fisheries, which integrated common property theory with oligopoly models, which highlighted how strategic quantity choices in and outside perfect competition could create inefficient harvest levels. This result provides a valid framework for examining entry, rent dissipation, and institutional reform within renewable resource industries.

Economic Characteristics of Commercial Fisheries

A feature that can be used to characterize commercial fisheries is that fish stocks are a renewable but exhaustible resource. Biological growth restocks fish populations over time, but is limited: overfishing can outpace natural regeneration, which leads to diminishing stocks or the eventual collapse of a fishery. Different from manufactured inputs, fish populations are not privately owned under open access authorities, which makes exclusion impossible and encourages overuse. The cost composition of fishing is reflected in the biological state of the resource. Whenever fish stocks are in excess, harvesting costs are low due to the ease of locating and capturing fish. By contrast, when stocks decline, marginal harvesting costs are increased, which requires greater effort, lengthier fishing trips, and a greater level of capital-intensive methods to obtain the same catch. Individual firms make note of this effect on their own costs, but do not internalise how their harvest choices lead to rising costs for other fishermen by reducing the group's overall stock. The market demand for fish products is usually downward sloping, with the given market price being determined by total industry output. All individual firms' harvests contribute to the collective supply; hence, they influence price, which creates strategic interdependence between firms. This interdependence is of great significance to the Cournot structure, in which firms decide quantities simultaneously while anticipating the effect of their choices on overall market outcomes. Lastly, many fisheries operate under open-access settings, which allow for free entry until economic profits are steered to zero. Entry aggravates overfishing by increasing total effort and accelerating rent dissipation, which reinforces the inefficiencies created by strategic competition and stock externalities.

Cournot Model Applied to Fisheries

As stated, commercial fisheries can be modelled as a Cournot oligopoly, which is defined by various fishing firms simultaneously choosing harvest quantities while taking the output of other firms as a given. Every firm in this environment is assumed to act independently and to maximize profit, with them recognizing that the market price of fish is dependent on the total industry catch instead of its own harvest alone. This structure highlights the strategic interdependence trait of commercial fishing industries.

Firms

Consider an industry with N fishing firms. Each firm i decides a harvest level q_i and the total harvest is given by the equation:

$$Q = \sum_{i=1}^N q_i$$

Firms are symmetric and battle in quantities, which reflects the fact that fishers choose how much effort to apply or how much to harvest before the realization of prices.

Market

Market price is set by total catch by means of a downward-sloping inverse demand function, $P(Q)$ where price falls as total supply increases. Each firm comprehends that increasing its own harvest will lead to the rise of total output, which in turn lowers the market price garnered by all firms, including itself. This price effect is central to the Cournot environment and differentiates it from perfectly competitive behaviour.

Costs

Harvesting costs are dependent on the biological condition of the fish stock. Whenever stocks are abundant, the ease of catching fish is greater, and marginal costs are effectively relatively low. As the stock decreases, greater effort is required to catch the same number of fish, which raises marginal costs. Significantly, each firm addresses the stock level as given when determining its choice, even though aggregate harvesting affects future stock abundance. The outcome is the creation of a stock externality that is not internalised by individual firms.

Firm Optimization

Every firm decides its harvest to maximize profit:

$$\pi_i = P(Q)q_i - C(q_i, S)$$

* S denotes fish stock

$$\frac{\partial \pi_i}{\partial q_i} = P(Q) + q_i P'(Q) - \frac{\partial C(q_i, S)}{\partial q_i} = 0$$

This first-order condition determines the firm's optimal harvest level. Solving this expression gives the firm's best response function.

Taking the harvest of other firms as constant/fixed, each firm draws a best response reaction function, which defines its optimal harvest as a function of total output by its competitors. The reaction function slopes downwards. As the harvest of rivals increases, the firm optimally decreases its own catch because of lower prices. The Cournot equilibrium occurs at the intersection of reaction functions from all firms.

The Cournot equilibrium is characterized as the group of harvest quantities (q_1, \dots, q_N) such that every firm's harvest is a best response to the harvest quantities chosen by all other firms. It's at this equilibrium that no firm can increase profit by unilaterally altering its own catch. In the setting of fisheries, Cournot equilibria lead to excessive harvesting relative to the socially optimal result. To make it more vivid, it is useful to make a comparison between three benchmark cases: monopoly, not oligopoly, and perfect competition. Within a monopoly, a single firm has control over the fishery and decides the total harvest to maximize long-run profit. Given that monopolists internalise the effect of harvest on price and future stock levels, output is restrained, and the resource is preserved. This results in the lowest harvest and highest stock level among all three cases. Within Cournot oligopolies, all firms internalise the price effect of their own output but subsequently ignore the impact of harvesting on the stock obtainable to other firms and themselves in future periods. Total harvest is therefore larger than under monopoly, but smaller than under perfect competition. Nonetheless, collective output consistently exceeds the socially optimal level, which leads to stock depletion. Under perfect competition, each firm acts as a price taker and neglects both price and stock effect, which results in the highest total harvest and the most detrimental example of overfishing. Overall, as the number of firms grows, total harvest in the Cournot equilibrium grows monotonically, gradually approaching the competitive outcome. This rise of aggregate catch speeds up stock depletions and dissolves economic rents. The resultant effect is known as the tragedy of the commons: strategic quantity competition lends a hand to ineffective high harvest levels, lowered fish stock, and diminished long-run profits for the industry, all in all.

A relevant addition to the Cournot model in fisheries is the appearance of free entry. Under open access conditions, firms can enter the fishery in any case where positive economic profit is present. The free entry condition shows that entry continues until profits reach zero in the long run. Confirmedly in equilibrium:

$$\pi_i = 0 \text{ for all firms } i$$

Although zero profits may seem efficient from a competitive viewpoint, amongst fisheries, this outcome reflects rent dissipation rather than optimal resource use. Because fish stocks are a valuable natural asset, they create scarcity rents. However, when access is left unrestricted, these rents are competed away through unrestrained entry and effort. Every additional firm ignores the negative externality it forces on others by reducing the available stock and increasing harvesting costs on a cross-industry scale. As a greater number of firms enter the market, total harvest increases, which moves prices down and decreases stocks. Individual firms respond rationally by increasing effort to maintain revenue, which further accelerates stock exhaustion. In equilibrium, all potential resource rents are dissipated by higher cost and lower stock levels, although aggregate revenue may continue to be high. The industry uses excessive

labour and capital to harvest fish that could have been harvested at a significantly lower cost under coordinated management. Effectively, this outcome is inefficient as the zero-profit equilibrium fails to maximize social surplus. A social planner is likely to restrict entry and harvest to protect stock levels and capture resource rents over time. Rather, open access leads to a well-known tragedy of the commons, characterised by individual rational behaviour as a result in grouped sub-optimal outcomes. The Cournot structure sheds light on how strategic quantity competition, mixed with free entry, transforms valuable natural capital into misspent economic effort and environmental degradation.

The present inefficiencies of Cournot competition become glaring when the dynamic nature of fish stocks is considered. Fish populations biologically increase as time goes on, usually according to a growth function that is dependent on the current stock level. Nonetheless, harvesting decisions are often myopic, with focus diverted away from long-term stock dynamics and placed on short-run profits. In the short run, firms regard the stock as a fixed quantity and decide harvest levels based on current prices and costs. The Cournot equilibrium in this situation already forms an outcome of an excessive harvest relative to the social optimum. Differently, in the long run, repeated overharvesting diminishes the stock, raises marginal cost, and decreases productivity. Firms then respond by increasing effort to counterbalance diminishing catch rates, which further worsens stock depletion. This separation between biological growth and economic decision-making generates a risk of complete stock collapse. When aggregate harvest continually is at a greater magnitude than biological growth, stock runs the risk of falling below critical thresholds from which regrowth is or close to impossible. Individual firms fall short in accounting for this risk because the benefits of restraint are shared across all firms, while the costs are created privately. To add strategic interaction magnifies this problem. Each firm anticipates that rivals will not cease harvesting aggressively, which reduces their incentive to conserve. As a result, the dynamic Cournot equilibrium will not only be inefficient but also ecologically unstable, which threatens the long-term vitality of the entire fishery.

Policy Implications

Policy implications play an essential role in correcting Cournot outcomes. Touching on the inefficiencies created by Cournot competition and free entry, policy intervention becomes a necessity for the realignment of private incentives and social objectives. Functional policies work by changing a firm's best response function, thereby altering equilibrium outcomes. An example of effective policy is limited entry, which restricts the number of firms that can operate in each fishery. Through reducing the number of competitors, limited entry decreases the total harvest and acts towards the preservation of stock levels. This allows for resource rents to persist. Therefore, the equilibrium is moved closer to the socially optimal outcome by reducing rent dissipation. A more accurate policy instrument is Individual Transferable Quotas (ITQs). Inside an ITQ system, firms are given rights to a fixed share of the total allowable catch. This is because the value of quotas depends on stock health, and firms are incentivised to conserve the resource. Through a game-theoretic perspective, ITQs internalize the stock externality by making conservation a part of every firm's payoff; this transforms aggressive harvesting from a dominant strategy into a costly strategy. The taxation of harvest can also act as a means of correction for Cournot outcomes.

By means of increasing the marginal cost of fishing, taxes can reduce optimal harvest levels in each firm's profit maximization problem. However, taxes need accurate information about stock dynamics and demand settings, which may prove challenging to acquire. Compared ITQs are typically more useful because they directly address incentives instead of relying only on price signals. Limited entry and taxes can reduce overfishing, but ITQs fundamentally transform static behaviour, in turn making sustainable harvesting a best response. In unison, these policies draw out how institutional design can fix the inefficiencies inherent in Cournot competition and propagate long-run economic and ecological preservation and sustainability.

Conclusion

In closing, commercial fisheries portray strategic quantity competition that generates stock externalities, rent dissipation, and ecological inefficiency. When modelling fisheries as Cournot oligopolies, the question of why rational profit-maximizing behaviour leads to overfishing under open access is answered. Effective institutional decisions, i.e., quotas and entry restrictions, are essential for achieving sustainable welfare-maximizing results.

Through a broader perspective, this investigation shows that the structure of fisheries, many being independent harvesters exploiting a shared renewable stock and competing in quantities, will lend itself to a Cournot system. Through explicitly linking biological stock dynamics, market demand, and firm optimization, this model straightens out how decentralized decision making diverges from the social optimum and why policy must be used to alter incentives rather than merely to restrict output. Modelling fisheries as a Cournot oligopoly benefits future economic analysis by providing a valid structure for evaluating entry, strategic interaction, and institutional reform. While at the same time the system has limitations, real fisheries may feature heterogeneous firms' uncertainty in stock assessment, spatial complexity, and behavioural considerations that extend beyond the scope of quantity competition. By recognizing these limitations, space is opened for future research in incorporating dynamic games, stochastic growth, or cooperative arrangements. In the end, the purpose of this analysis was not only to diagnose overfishing but to shed light on how economic structure can inform institutional design and long-run sustainability.

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