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# Fisheries regulation: A survey of the literature on uncertainty, compliance behavior and asymmetric information

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ABSTRACT

Economists normally claim that a stock externality arises within fisheries because each individual fisherman does not take the effect on stock size into account when making harvest decisions. Due to the stock externality, it is commonly argued that fisheries regulation is necessary, but regulatory decisions are complicated by a tremendous amount of uncertainty and asymmetric information. This paper provides an overview of selected parts of the literature on the regulation of fisheries under uncertainty and asymmetric information, and possible areas for future research are identified. Specifically, three main topics are covered. First, the issue of choosing regulatory instruments under uncertainty is discussed. Second, compliance and enforcement problems caused by fisheries regulation are investigated. Third, alternatives to a traditional enforcement policy are presented.

## 1. Introduction

It is normally argued that a stock externality arises in fisheries because each individual fisherman disregards the resource restriction.[1] The stock externality implies that the fisherman does not take the effect of his harvest on stock size, and thereby the harvest of other fishermen, into account when making decisions. Given the stock externality, economists often argue that regulation of fisheries is necessary, and it is common to regulate output (harvest) in developed countries, whereas developing countries mainly use input (effort) regulation (see, e.g., [44]).

However, fisheries regulation is complicated by the existence of a tremendous amount of uncertainty and asymmetric information,[2] which is reflected in at least three ways in the literature. First, a well-known result is that both taxes and individual transferable quotas (ITQs) can generate optimal harvest under full certainty. However, under uncertainty, the efficiency properties of taxes and ITQs may differ,[3] in which case the regulator faces two possibilities. One possibility is to adjust one regulatory instrument (a tax or an ITQ) to incorporate uncertainty; this solution is often labelled the second-best choice between price and quantity regulation. Another possibility is to combine several regulatory instruments to solve the problem associated with uncertainty and thereby reach a first-best optimum.

Second, under many types of quantity regulation, compliance problems arise, making an enforcement policy necessary.[4] From a fisherman's perspective, an enforcement policy implies that the probability of detection and the size of an expected penalty shall be taken into account when making decisions. Furthermore, non-compliance with fisheries regulations can be viewed as an example of a criminal activity and the economics of crime can be used to analyze fisheries enforcement.[5]

Third, it is important to study regulatory mechanisms under which an incentive for full compliance exists. In this case, one option is to use the fact that non-compliance behavior implies that individual harvest is unobservable due to illegal landings, and thus, a problem with asymmetric information (moral hazard) arises (see, e.g., [59]). This

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[1] Examples of other externalities in fisheries include $CO_2$ emissions (see, e.g., [84]), by-catches (see, e.g., [12]), high-grading (see, e.g., [78]), harvest substitution between quota and non-quota species (see, e.g., [8]) and non-fisheries related benefits (see, e.g., [73]). Examples of other market failures include imperfect competition (see, e.g., [18]), stock uncertainty (see, e.g., [68]) and asymmetric information about costs (see, e.g., [52]).

[2] See Jensen [45] for an overview of uncertainty and asymmetric information problems that arise in a fisheries context.

[3] Taxes and ITQs also differ with respect to the property right to fish stocks. With taxes, the property right belongs to society, whereas the fishermen own the resource under ITQs (at least under grandfathering).

[4] Compliance problems also arise with price (tax) regulation and Allingham and Sandmo [3] is a classic contribution within general economic theory on tax avoidance.

[5] See Becker [11] for the seminal contribution within the economics of crime.

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problem is similar to a non-point pollution problem, and therefore, incentive mechanisms from the non-point pollution literature can be translated into a fisheries context. In a non-point pollution setting, the regulator can either control inputs or the aggregated pollution to solve externality problems.

This paper investigates fisheries regulation under uncertainty and asymmetric information from a theoretical perspective by providing an overview of selected literature on the following three issues: 1) instrument choice under uncertainty, 2) compliance and enforcement problems, and 3) non-point pollution mechanisms in a fisheries context. Under the first topic, literature on both the second-best choice between price and quantity regulation and combinations of several regulatory instruments is investigated. For compliance and enforcement problems, we only investigate literature on output and input regulation, whereas literature targeting both the aggregated pollution and the input use is reviewed under the third topic.

The environmental economics literature has been an important source of inspiration for the fisheries economics literature on regulation. For this reason, we summarize a few classic and important papers within environmental economics that have inspired fisheries economists with respect to each of the three topics. However, an important difference between environmental economics and fisheries economics arises. Most papers within environmental economics investigate a flow externality problem that arises when the behavior of one group of agents has a direct impact on the profit or utility of other agents, and the cost (or benefit) of the decisions is not reflected in a market transaction. A flow externality problem is normally discussed using a static model.[6] However, most papers on fisheries discuss a stock externality that arises when the behavior of one group of agents influences a stock variable. The stock variable then has an undesirable effect on the utility or profit of other agents, and this effect is not currently captured by market prices. When analyzing a stock externality problem, either a static or a dynamic model can be adopted. Due to differences in the nature of flow and stock externalities, the results from the environmental economics literature cannot necessarily be generalized directly to fisheries economics, as illustrated in the present paper.

Another difference concerning the nature of externalities arises when comparing the environmental economics and fisheries economics literature. If the damage of pollution influences a group of agents, environmental economics investigates a public bad, whereas a fish stock is a public good. Thus, pollution and fish stocks differ with respect to the sign of their influence on the objective functions of the affected agents. However, we will not use the distinction between public goods and bads in this paper; instead, we focus on the difference between flow and stock externalities.

Furthermore, we make three simplifying assumptions in the present paper. First, for fisheries, we only consider a stock externality, implying that market failures such as congestion and imperfect information are not investigated. Second, only papers on single-species models are included; therefore, multi-species interaction is excluded. Finally, as an example of a flow externality, we use traditional pollution. This choice seems reasonable given that the overview of the classic results in the environmental economics literature becomes clear by this choice.

Three other papers have reviewed parts of the fisheries economics literature summarized in this paper. Jensen [45] reviews the fisheries economics literature on both the second-best choice between price and quantity regulation and attempts to translate non-point pollution mechanisms into a fisheries context. However, the link to classic results in the environmental economics literature is not identified by Jensen [45]. Nøstbakken [65] compares general economics and fisheries economics literature on compliance and enforcement problems but does not identify important areas for future research. Vestergaard [79] summarizes literature applying a principal-agent approach to fisheries, but the principal-agent literature is not included in the present literature review. Thus, overall, we make important contributions to the existing fisheries economics literature covered by Jensen [45], Nøstbakken [65] and Vestergaard [79].

The remainder of this paper is organized as follows. In Section 2, basic issues regarding the regulation of flow and stock externalities are described verbally, whereas instrument choice under uncertainty is discussed in Section 3. Compliance and enforcement problems are treated in Section 4, and translation of non-point pollution mechanisms into a fisheries context is discussed in Section 5. Section 6 briefly summarizes the results of the literature review.

## 2. Flow and stock externalities

This section introduces basic results regarding the regulation of externalities under complete uncertainty and symmetric information. Specifically, both a flow externality and a stock externality are discussed (Section 2.1), and the three topics (instrument choice under uncertainty, compliance and enforcement problems and non-point pollution mechanisms) are related to the discussion of the two externalities (Section 2.2).

### 2.1. Regulation of flow and stock externalities[7]

#### 2.1.1. A flow externality

A flow externality arises when the choices of certain agents has a direct effect on the utility or profit of other agents´ profit and utility function, and this impact is not captured correctly by market prices. We use pollution as an example of a negative flow externality. Pollution has been treated in two different modeling set-ups in the environmental economics literature. First, pollution has been modeled as a by-product arising when producing an output, and in this case, pollution is not a direct control variable (see, e.g. [27]). Second, pollution has been viewed as a separate output or input, and in this case, pollution is a control variable (see, e.g. [10]). The literature reviewed in this paper mainly uses the latter approach; therefore, pollution is treated as a control variable. Specifically, we assume that a representative firm produces an output to maximize the net benefits of an industry,[8] and these benefits depend on both the output and pollution.[9] When the net benefits are maximized, the firm´s first-order conditions with respect to pollution are such that the marginal net benefit of pollution shall be equal to zero.

Turning to the regulator, it is assumed that pollution generates damages on other consumers and/or producers, and the size of this damage depends on the quantity of pollution. Based on this description of the damage, pollution affects the utility or profit of other agents, directly capturing the basic nature of a flow externality. Now, welfare can be defined as the net benefits for the firm minus the monetary cost of the damage imposed on other agents. Because a flow externality is considered, a static decision-making problem arises, implying that only current welfare is maximized by the regulator. The first-order condition for the optimal quantity of pollution states that the marginal net benefits are equal to the marginal damage. Based on this description, it is clear that the regulator takes the marginal damage of pollution into account, whereas the firm excludes this damage.[10] Thus, the marginal

[6] In fisheries economics, congestion on fishing grounds is an example of a flow externality.

[7] Mathematical models for the regulation of both the flow and stock externalities on which this description is based are available upon request from the authors.

[8] The net benefit can be understood as the profit defined as the revenue minus the costs, but it is useful to use the net benefit concept in this paper given the literature reviewed in Section 3.

[9] Three facts associated with this model should be noted. First, externalities can also be positive. Second, externalities can also arise from using production factors. Third, externalities can also arise from consumption goods. However, the main results discussed in this section generalize these three situations.