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Harvest efficiency and fishery discards under harvest uncertainty and trading restrictions

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ABSTRACT

We study harvesting efficiency and the problem of discards under harvest uncertainty in a fishery that is managed with quotas. With only idiosyncratic harvest uncertainty, we show that frictionless post-harvest quota trade can achieve full efficiency and eliminate quota-overage discards completely. In the absence of such trade, we deduce an *ad valorem* tax/subsidy that eliminates discards while delivering a desired aggregate harvest target. Alternatively, we show that a hybrid policy, i.e., a combined quota and landings fee, can implement a manager's aggregate target harvest level efficiently and without discards. When harvest shocks, in addition, have a fishery-wide common component, post-harvest quota trading *per se* cannot eliminate discards; policy intervention in the form of either landing taxes or a hybrid scheme is needed. Given the prevalence of trading restrictions in many quota-managed fisheries worldwide, our paper offers important policy advice.

Introduction

Growing evidence finds that property rights-based management approaches such as individual fishing quotas can address stock conservation goals and improve economic efficiency in marine fisheries (Costello et al., 2008; Committee to Review Individual fishing Quotas, 1999; Grafton et al., 2006). However, harvesting fish is inherently a stochastic process. A concern among resource managers is that fishermen operating under a harvest quota constraint will have difficulty matching random catch with quotas (Copes, 1986; Squires and Kirkley, 1995; Squires et al., 1998; Sanchirico et al., 2006). Faced with an unanticipated overage, i.e., a harvest in excess of the quota held, the fishermen may be forced to discard fish at sea to avoid regulatory penalty. Regulators fear that catch-quota imbalance will further aggravate the problem of wasteful at-sea discards, which recent estimates put at 7.3 million metric tons of fish per year worldwide, or 8% of the global catch (Kelleher, 2005).[1]

In response to this problem, most quota program designs include stipulations, of some form, that are intended to help fishermen match harvests and quotas.[2] Examples of such stipulations, or quota balancing mechanisms, include rollover provisions that allow quota reallocation across fishing seasons, *flexible* quota that can be used to land a group of different

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[1] Estimates of the share of fishery discards caused by unanticipated catch-quota imbalance are not available at the global level. Catchpole et al. (2014), estimate that quota restrictions accounted for, on average, 22% of total discards in a sample of English, French, Danish, Greek and Spanish fisheries during 2002–2010. See Condie, 2013 for additional discussion of over-quota discarding.

[2] See Sanchirico et al. (2006) for a review of quota balancing approaches used in fisheries worldwide.

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fish species, deemed value payments which allow fishermen to land catch overages if they pay a fee to the regulator, and permission to surrender or discard catches that do not match quotas. The role of quota-balancing mechanisms in reducing discards and their implications for the function and performance of quota-based management approaches has not been thoroughly examined.[3]

Many quota-based management programs also include restrictions and, in some cases, strict limits on quota transferability.[4] The rules governing transferability vary widely across fisheries. For example, the US west coast and Alaska halibut quota management program requires the registered owner of quota to be on board the vessel while the owner's quota is being fished. This rule effectively removes the possibility of obtaining additional quota to cover an unanticipated halibut catch. In the US Pacific groundfish fishery, fishermen are allowed a 30-day grace period from the date of harvest to purchase additional quota if needed. However, these same fishermen face caps on the total quota, by species, that they can own; caps range between 4 and 15% of total available quota. The British Columbia, Canada Integrated Groundfish Program allows permanent trades and leasing of quota among some sectors of the groundfish fleet, but not others.

Discards of marketable fish, to which over-quota discards contribute, are symbolic of a failure to achieve sustainable management goals under the European Union's Common Fisheries Policy (Condie et al., 2014; CEC, 2009; Gilman, 2011; Hatcher, 2013). Currently, aggregate quotas are distributed to member states who are free to manage allocations and impose rules for transferability as they wish. A relatively small number of member states allow quota transfers within their own fleets; transfers across member states are prohibited (Agnew et al., 2010). While recent analysis finds that individual transferable rights may reduce discards in EU fisheries, restrictions on transferability remain (see Agnew et al., 2010). Provisions that raise the cost of quota trading, e.g., caps on ownership concentration, limits on transferability between small and large scale fleets, and provisions to discourage quota ownership by fishery non-participants are often included to counter the potential negative social impacts of transferability.

With this background, our paper has three main objectives. First, we study production behavior under harvest uncertainty in the absence of quota trade. In particular, we explore how *ex ante* harvest production plans and *ex post* realized harvest distributions evolve endogenously in response to aggregate quota allocations and exogenous harvest shocks. To the best of our knowledge, no such exercise has been undertaken in previous research. Second, we show that harvest plans are efficient when quotas can be traded at all stages of fishing operations. Finally, we study policies that can implement efficient plans in the absence of post-harvest quota markets.

Our analysis builds a case in favor of removing restrictions on quota trading to address the catch-quota balancing problem. We show that trade can achieve fully efficient harvesting under decentralized quota management and mitigate discards that would otherwise occur due to unanticipated catch-quota imbalance. The reason is quite simple: a fisherman who realizes a random harvest in excess of his *ex ante* expectation and quota holding has already sunk fuel, bait, and labor costs required to capture the fish. Another fisherman whose harvest falls below expectation will trade unused quota to cover the overage at any positive payment. A trade will definitely occur since the gain from this trade equals the dockside value of the already harvested catch overage. Unrestricted quota trading, while fishing operations are ongoing at sea, allows such opportunistic exchange; both *ex post* discards and redundant *ex ante* allocation of harvest effort are averted. We show that if harvest randomness is solely idiosyncratic, frictionless trade in quotas can implement efficient harvest plans and completely eliminate discards. However, if harvest shocks, in addition, have a common fishery wide component, further policy interventions are needed.

We demonstrate the above intuition and other implications of quota transferability in a simple model of decentralized harvesting under quota management and a diminishing returns stochastic harvest technology: *ex ante* identical fishermen employ inputs to harvest an expected catch that matches their individual quota holding. An input-dependent random harvest is then realized. We derive equilibrium quota prices, harvests, and landings, and evaluate efficiency and discards both in the presence of a well-functioning, pre- and post-harvest quota trading market, and when post-harvest quota trade is prohibited by regulation (or is excessively costly).

To begin with, we consider fishermen-specific idiosyncratic harvest shocks with no common component. In the absence of post-harvest quota trade, aggregate landings are less than the managers' target quota, while at sea discards remain positive. This is because quota exchanges between fishermen who realize random harvest overages, and those who realize random harvest underages, do not occur. Absence of quota exchanges also implies an excessive, redundant allocation of factor inputs, or effort. In contrast, harvesting operations are fully efficient in the sense that quotas are fully utilized and discards are completely eliminated when such exchanges occur through quota trade.

Our analysis highlights several interesting dimensions of equilibrium harvest plans in the absence of quota trade. First, aggregate harvest may fall below or above the quota depending on whether the quota is above or below an endogenously determined threshold value. Second, whether the quota is set below or above this threshold also determines whether an increase in harvest volatility increases or decreases *ex ante* input employment, expected harvests, and quota prices. Third,

[3] The incentive to discard fish in quota-managed fisheries has been examined by several authors (Copes, 1986; Rettig, 1986; Arnason, 1994; Boyce, 1996; Vestergaard, 1996; Squires et al., 1998; Hatcher, 2005; Herrera, 2005; Holland, 2010). Much of this literature is concerned with matching quotas to harvests of a target and a jointly harvested or *bycatch* species in a deterministic setting.

[4] Regulations governing quota transferability are required in U.S. fisheries under the Magnuson-Stevens Act Reauthorization of 2006.