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Technical change in fisheries

Dale Squires [a], Niels Vestergaard [b,*]

[a] NOAA Fisheries, Southwest Fisheries Science Center 8604 La Jolla Shores Drive, La Jolla, CA 92037 USA
[b] Department of Environmental and Business Economics and Centre for Fisheries & Aquaculture Management & Economics (FAME), University of Southern Denmark, Niels Bohrs Vej 9, DK-6700 Esbjerg, Denmark

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ABSTRACT

Technical change in fisheries is an under-researched area in resource economics and management. This is surprising, because technical progress is the main driver of the development in fishing power and capacity. This article reviews the recent research and development in technology that have occurred in fisheries. New policy implications of introducing technical change into the standard bioeconomic model are illustrated. Bycatch saving technical change is critical to bycatch reduction and ecosystem based fisheries management, and optimal policies cost-effectively reduce bycatch, create incentives to induce bycatch saving technical change, and establish technology policy for research and development.

1. Introduction

Technical change in fisheries is ubiquitous and far more important than often realized. It is one of the main driving forces behind the historical development of fishing, status of resource stocks, growth in productivity or fishing power, extension of fishing grounds by depth and geographical range, broadening of species harvested, increased habitat destruction, reductions in bycatch, responses to regulations, and more. Since global industrial fishing fleets have largely been built up by about 1990 [1], the main impetus of increasing fishing capacity, and much overexploitation, is technical change. Technical change has been no less transformative in the processing and distribution sector than in the harvesting sector, with refrigeration and freezing altering product forms and consumption patterns, and railways and trucking altering distribution of fresh and frozen products to what is now a global scale. Technical change in processing and distribution helped fuel the technical change in the harvesting sector through creation of markets. Although important and pervasive, technical change has received insufficient attention in the fisheries literature.[1]

Similarly, bioeconomic modeling and fisheries policy have been formulated in a world without technical change, concentrating on physical and natural capital accumulation, which as this paper demonstrates, can give very misleading policy advice. Dynamic problems in fisheries, and largely in renewable resource economics, have not been formulated or considered in a world with changing technology; capital dynamics have been static in technology, even though technical change along with capital accumulation are the primary driving forces of economic growth.

In this paper technical change in the fisheries harvesting sector is examined, concentrating on the economically optimum harvesting of fisheries with and without technical change, technical change that responds to, or is induced by, regulations, and biased bycatch saving technical change that is induced by increasing scarcity of bycatch, rising social valuations of bycatch, and consumer market effects. Economic policies to maximize resource rent are also considered when technical change is added to dynamic bioeconomic models and bycatch and technology policies that reinforce one another and establish incentives for inducing bycatch saving innovations.

Section 2 surveys some of changes in technology that have occurred in fisheries and reviews the literature. Section 3 reviews types of technical change, including disembodied, embodied, biased, exogenous, endogenous, and induced (including directed). Section 4 introduces technical change into the basic dynamic bioeconomic model to show that very different dynamic economic optimums are reached from the conventional wisdom and draws out some of the policy implications. Section 5 addresses the impact of endogenous, induced technical change upon bycatch

* Corresponding author. Tel.: +45 601 141 81.
E-mail addresses: Dale.Squires@noaa.gov (D. Squires), nv@sam.sdu.dk (N. Vestergaard).

[1] Measurement of changes in fishing power or productivity has received considerable attention, but not the implications for optimum use. Similarly, population biology is concerned with time varying catchability [2].

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reduction and the importance of bycatch reduction policies that create incentives that also induce bycatch saving technical change. It also examines technology policy for the socially optimal research and development (R&D) for induced bycatch saving technical change. Section 6 offers concluding remarks.

2. Technical change in fisheries

Technical progress has contributed to the growth and development of fisheries, but also to their overexploitation [3–5]. Technical change embodied in fishing fleets has markedly contributed to the increased global harvesting capacity of fisheries and increased exploitation. The rapid technological progress over the past century undoubtedly contributed to the decline of most, if not all, global fisheries. Subsidies may have accelerated the adoption of technical progress embodied in stocks of physical capital (electronics, gear, equipment, hull). Rapid advancements in fishing technologies led to increased fishing pressure on all fish stocks in the 20th century, calling into question the late 19th and early 20th Century belief of an inexhaustible bounty from the ocean (cf. [6]).

Fishing underwent its own industrial revolution in the nineteenth and twentieth centuries and its own information technology (IT) revolution beginning in the middle of the twentieth century and into the twenty-first century. Mechanical power for vessels replaced sail power in the 1880s, when the first British coal-fired steam trawlers were used, allowed development of new gear types (e.g. otter trawl in 1882) and substantially larger vessels and gear and exploitation of fish stocks in previously inaccessible ocean locations and depths and at substantially higher levels of productivity [7]. Winches were introduced to haul gear, with steam capstans used for hauling drift nets by the early twentieth century, and modern descents remaining in trawling and seine-netting. Steel hulls replaced wood. Engines became more powerful and fuel-efficient, with oil-fired steam engines and internal combustion engines entering the picture after World War I. Marine diesel engines, introduced in the late 1940s, were more efficient and compact than steam engines, allowing significant savings in fuel usage and space. A critical innovation was the introduction of synthetic materials for gear around 1950. The power block for purse seiners in the 1950s significantly reduced labor involved in preparing and moving equipment and allowed larger nets and vessels. Small-scale, traditional fisheries are now motorized, use net haulers and synthetic gear materials, employ cell phones to compare fish prices, and more.

Vessel IT, such as sonar, LIDAR, chromoscopes, satellite and thermal imaging, cell phones, broad-swathe mapping of the seabed, bird radar, global positioning systems, route tracers, and other hydro-acoustic devices all help communications, navigation, locate fish, monitor gear performance while fishing, and develop markets. The key developments in navigation and fish finding after World War II were radio position fixing (principally DECCA and LORAN) and echo-sounding that subsequently developed into sonar. In the late twentieth century, position-fixing has become primarily reliant on GPS. More generally, IT-based knowledge of modern electronic equipment, communications, and satellites increasingly supersedes local traditional and craft knowledge, leading to price-induced substitution of the firm's management and other labor services, also raising their marginal products and thereby increasing their services [8], but also allows expansion in output through fishing in new areas and depths (for example) and raising the overall skill level of average and below average skippers [4]. The quality of IT-embodied capital, such as electronics, has steadily improved and unit costs fallen, increasing the rate of adoption and diffusion, a form of price-induced technical change [8]. Old and new vintages of related technologies may co-exist, such as radio and internet access or Loran C and GPS on the same vessel and steel and wooden hull vessels in the same fishery. Rates of diffusion differ by fishery.

The normative economics literature on common renewable resources has largely overlooked technical change, instead developing bioeconomic models with static technology focusing on steady-state levels of effort or physical capital stock, resource stock (natural capital), yield, and their dynamic approaches under constant technology [9–12]. Squires and Vestergaard [4] introduced technical change into the dynamic bioeconomic model (see below).

Smith [13] found that an unpriced common resource induces technical change in favor of increased utilization of this unpriced resource and that the competitive pressures of the race for fish can compel firms to adopt innovations and provides an endogenous source of growth. Townsend [14] identified several incentives in limited-entry fisheries for increased use of capital, but does not mention technical change. Smith and Krutilla [3] observed that technical change under open access accelerates the dissipation of resource rent and depletes resource stocks that are already over-exploited. Whitmarsh [5] and Squires and Vestergaard [4] made similar observations.

3. Technical change

Technical change refers to changes in techniques of production at the firm (vessel) or industry level resulting from application of new knowledge of scientific, engineering, or other principles to techniques of production. It excludes changes in factor (input) productivities that result in choices among known techniques or from changes in the output mix due to changes in the relative prices of inputs or outputs [15]. Technical change can lead to lower costs per unit of effort or increased catch rates per unit of effort given any level of resource stock.

Economic incentives play an essential role in the process by which new knowledge is introduced into the production process by new ways to find, capture, and handle fish. Not everyone who contributes to technical change is motivated by economic incentives, but nonetheless, economic incentives play a fundamental role.

New production processes are *process innovations* and new products are *product innovations*. Process innovations are those innovations not apparent in the physical properties of the product and alter the way products are made, whereas product innovations affect the physical properties of the product and require some consumer adjustment. The power block or new ways to catch fish are process innovations and new species harvested are product innovations. Although the distinction is not always clear, such as new species harvested because of fishing in previous inaccessible areas (e.g. harvesting grenadier on the deep continental slope), fisheries harvesting is largely concerned with process innovations.

Exogenous technical change occurs when technical change and its rate are largely independent of economic forces. The exogenous source is assumed to reflect progress in science, and in fisheries reflects its antecedents in military, aerospace, and IT sectors [4]. The major assumption is that access to technology is free and is publicly available as a non-excludable, non-rival good. (Rivalry refers to whether or not consumption of a good depletes the amount available for another's consumption.) Exogenous technical change is sometimes call “manna from heaven.”

Disembodied technical change refers to technical change that is not embodied in an economic input, notably the capital stock or is not investment-specific, i.e. it is independent of physical capital