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The social cost of fishery subsidy reforms

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ABSTRACT

This paper analyzes the impact of reducing fisheries subsidies in a general equilibrium model for a fishery with heterogeneous vessels. It considers the impact of the stock effect, which determines the participation of vessels in a likely increased stock abundance. In equilibrium, the productivity of the fleet is endogenous as it depends on the stock of fish along the equilibrium path. The model concludes that any impact of a subsidy drop will depend on the stock effect. If that effect is large, fishing firms will benefit from the stock recovery and the elimination of the subsidy will increase future returns on investment. The model is particularised to industrial shrimp fisheries in Mexico. It is shown that the complete elimination of a subsidy increases biomass, capitalisation, marginal productivity, and consumption and reduces inequality when the effect of the induced increase in the stock is considered. However, if that effect is not considered, capital and consumption decrease, and inequality and hence, the social costs of a subsidy drop, increase.

1. Introduction

Subsidies in the fishing industry involve important resources and have implications on capitalisation and on the effort of fleets. For example, Sumaila et al. [1] show that total subsidies on fisheries were about 35 billion dollars in 2009. This is close to the earlier estimate for 2003 subsidies after adjustment for inflation [2]. According to this analysis, fuel subsidies accounted for 22% of total subsidies in fisheries. They also conclude that subsidies provided by developed countries are greater (65% of the total) than those by developing countries (35% of the total) and that Asia is the greatest subsidizing region (43% of the total), followed by Europe (25% of the total) and North America (16% of the total). Japan provides the highest amount of subsidies (19.7% of the total), followed by the United States and China at 19.6% of the total. In this last country 95% of the subsidies are fuel subsidies, considered as harmful [3]. In the European Union (EU) total subsidies to the fishing sector are equivalent to 50% of the value of the total fish catch that year (EUR 6.6 billion) and fuel subsidies amount to half of all EU fishery subsidies. In the EU, fuel subsidies take the form of tax exemptions on fuel used for fishing. It is also remarkable how according to Schuhbauer et al. [4], worldwide, only 6% of the total fuel subsidies go to small scale fisheries (SSF).

Subsidies on fisheries have been discussed in recent meetings of the World Trade Organization (WTO). They are seen as a threat to the sustainability of many of the world's fisheries [5]. In these discussions the social consequences of fishery subsidies have been considered as one of the main barriers to their removal. Those consequences are particularly relevant in less developing countries. When analyzing these social consequences the heterogeneity of agents is an important aspect, given that this heterogeneity is the source of inequality.

This work analyzes the impact of reducing a subsidy on fisheries in a general equilibrium framework, for a fishery with heterogeneous fishing vessels. General equilibrium analysis of fisheries can be found in studies of multiple uses of the ecosystem [6]. These type of models can also explain how inputs are over-allocated to an open access resource and create a general equilibrium tragedy of the commons in artisanal fisheries [7]. The model selected extends the one used in Da-Rocha et al. [8] to include fishing firms' investment decisions, endogenously. Furthermore, the model is a dynamic version of Angeletos [9], in which there are incomplete markets where fishing firms cannot insure against their future productivity realizations.

The analysis performed is related to that of Sumaila et al. [10], who provide a theoretical analysis of an exogenous increase in fuel prices in a bioeconomic model. They conclude that an increase in fuel prices (equivalent to a reduction in fuel subsidy) shifts the total cost function upwards, which means a reduction of effort in the competitive equilibrium where total cost equals total revenue. They also show a similar effect of a

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subsidy reduction in the single owner maximization problem. Munro and Sumaila [11] also analyze subsidies in fisheries and show that the introduction of cost reduction subsidies has a negative impact on the resource. They conclude that subsidies imply over-exploitation even in a well managed fishery (by a fishery manager or in a fishery in which a fully fledged system of property rights that rules out the commons effect has been introduced).

In this work it is shown how subsidy elimination could increase inequality on fishing firms returns, although as a particular case in which the stock effect is not considered. However, when fishermen are forward-looking (that is, if the size of future stocks affects today's decisions) results may differ. When the stock effect is significant a reduction in over-capitalisation can be compatible with an increase in the marginal productivity of physical capital. This makes returns more similar across vessels, so social costs (measured in terms of inequality) are also reduced. Results obtained, provide insights that should be considered by any central authority managing a fishery; first, in terms of how to provide management advice of future natural capital (fish-stocks) and second on how to manage the physical capital of a fishery (vessels). This gives an important message on the size of the social costs of subsidies reductions that supplements earlier studies [1,2,10,12]. To provide a numerical example, the model is particularised to the industrial shrimp fishery in Mexico, which is one of that country's most valuable fishery [12].

The rest of the paper is organized as follows: Section 2 presents the model. Section 3 presents the general results from a subsidy reform obtained from the model. Section 4 shows a numerical illustration. Section 5 discusses the policy implications and Section 6 concludes.

2. The dynamic general equilibrium model

As mentioned in Section 1, the model used is a continuous time version of Angeletos [9]. There is a continuum of households endowed with one unit of labor which holds physical capital, k (i.e. a vessel with capacity k). There is idiosyncratic risk that affects each owner of capital, which reflects what happens in any privately-held business in a risky industry such as fishing. There are two markets in the economy: a market for final goods and a labor market which is required to produce the final good and in which wages are denoted by $w(t)$. Output price is considered as a numeraire. Finally, the government subsidizes production with a (negative) tax rate τ. Each vessel's output and profit depend on its production capacity as in Lazkano and Nostbakken [13]. Their production function depends on the size of the stock(s) (X), physical capital level (k) and use of variable inputs (n). It is assumed that natural (γ) and physical capitals (α) have the same elasticities when $\gamma = \alpha$. This assumption implies that in equilibrium the total harvested is given by a Schaefer type function [14]:

$$y = z^{\alpha}k^{\alpha}n^{(1-\alpha)}X^{\gamma} \tag{1}$$

Individual abilities (z) are modeled as differences in individual productivities between vessels. They are assumed to follow a stochastic process $dz = \mu_z z dt + \sigma_z d\omega$, where $E\omega = 0$ and $d\omega^2 = \sigma^2 dt$.

The representative household's utility function is given by:

$$\max \int_0^{\infty} e^{-\rho t}u(c)dt$$

where c is private consumption. It is assumed that $0 < \rho < 1$ and that utility (u) is continuously differentiable, strictly concave, and monotonically increasing. A constant relative risk aversion (CRRA) utility function is used:

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma},$$

where the parameter σ measures the degree of relative risk aversion.

The inter-temporal consumer's problem is given by:

$$\begin{aligned}
&v(z, k, t) = \max_{c,k} \mathbb{E}\left[\int_0^{\infty} e^{-\rho t}u(c)dt\right]\\
&s.\ t:\\
&dk = \left[\max_n\{(1+\tau)y - wn - \delta k\} + w - c + T\right]dt,\\
&y = z^{\alpha}k^{\alpha}n^{(1-\alpha)}X^{\alpha},\\
&dz = \mu z dt + \sigma_z d\omega,\\
&c, k \geq 0.
\end{aligned} \tag{2}$$

Expression (2) shows how consumers maximize utility given their expectations on the natural capital stock of X. The stock of capital affects the total factor productivity of the industry at all times. A larger stock increases profitability and raises the incentives to invest.

It is assumed that fishing possibilities are managed by announcing a path of mortality of fish. This path is a harvest control rule (HCR) that supports the equilibrium. HCRs are a set of pre-agreed rules used to determine a management response to changes in the indicators of stock status with respect to reference points with the objective of moving or maintaining the exploitation level of stocks to pre-defined levels. There is an output path associated with the HCR that supports the beliefs of fishermen about the trajectory of the stock. Therefore, the role of the HCR in this model is to guarantee the unicity of equilibrium.

The natural resource follows an age structured dynamic model as in [8], with the following conservation law [15,16]:

$$\frac{\partial n(a, t)}{\partial t} = -\frac{\partial n(a, t)}{\partial a} - [m(a) + p(a)F(t)]n(a, t). \tag{3}$$

where $n(a, t)$ is the number of fish of age a at time t and $p(a)$ is the proportion of the fishing mortality (F) allocated to each age. Therefore, the stock abundance function is defined as:

$$X(t) = \int_0^{A} \omega(a)n(a, t)da. \tag{4}$$

where ω is the weight at age. Finally, it is assumed that fish die at age A.

3. Results

The model is solved as a mean filed game [17]. Conditional on z, k and X, individual profits are obtained by solving an intra-temporal optimization problem. Each vessel solves:

$$R(w, \tau, X)zk - \delta k \equiv \max_n (1+\tau)y - wn - \delta k$$

where $R(w, \tau, X) = \alpha(1+\tau)^{1/\alpha}\left[\frac{(1-\alpha)}{w}\right]^{(1-\alpha)/\alpha}X$ and δ is the depreciation rate. Notice that $R(w, \tau, X)$ is increasing in X. Note also that profit per vessel is given by:

$$\pi(\tau, z, k, X) = \underbrace{\alpha(1+\tau)^{1/\alpha}\left[\frac{(1-\alpha)}{w}\right]^{(1-\alpha)/\alpha}X}_{R(w,\tau,X)}zk$$

Harvest per fishing vessel can be determined using:

$$y(\tau, z, k, X) = \frac{\pi(\tau, z, k, X)}{\alpha(1+\tau)} = \frac{R(w, \tau, X)}{\alpha(1+\tau)}zk = \underbrace{q(\tau, w)zkX}_{\simeq \text{Schaefer}(1954)}$$

And, given a measure $g(z, k, t)$, total effort follow the next equation:

$$K = \int zkg(z, k, t)dkdz.$$

Therefore, capital evolves according to:

$$dk = [R(w, \tau, X)zk - \delta k + w - c + T]dt.$$

Given $X(t)$, $w(t)$ and τ, $R(w, \tau, X)$ can be computed and a representative household chooses its consumption (c) and physical capital (k), by solving the following Hamilton-Jacobi-Bellman equation: