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A bayesian estimation of the economic effects of the Common Fisheries Policy on the Galician Fleet: a dynamic stochastic general equilibrium approach

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Abstract

What would have happened if a relatively looser fisheries policy had been implemented in the European Union (EU)? Using Bayesian methods a Dynamic Stochastic General Equilibrium (DSGE) model is estimated to assess the impact of the European Common Fisheries Policy (CFP) on the economic performance of a Galician (north-west of Spain) fleet highly dependant on the EU southern stock of hake. Our counterfactual analysis shows that if a less effective CFP had been implemented during the period 1986-2012, 'fishing opportunities" would have increased, leading to an increase in labor hours of 4.87%. However, this increase in fishing activity would have worsened the profitability of the fleet, dropping wages and rental price of capital by 6.79% and 0.88%, respectively. Welfare would also be negatively affected since, in addition to the increase in hours worked, consumption would have reduced by 0.59%.

Keywords: CFP, Bayesian Estimation, DSGE, Spanish Fleet
Classification: JEL Q22, Q28, C61; AMS 91B76, 92D25.

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1. Introduction

Within the European Union (EU), fisheries management programs had follow a decentralized approach: while government agencies aimed to control fishing mortality, private fishing firms decided, based on the consequent fishing possibilities, their fishing effort and future capacity levels. These fishing possibilities, decided upon overall management objectives (e.g., Maximum Sustainable Yield, -MSY-), were converted into Member State (MS) shares using fixed share system and at a MS level distributed among national fleets.

EU fisheries had historically failed on maintaining healthy stocks. This was probably due to the lack of an efficient institutional framework. However, a strong commitment on MSY objective set by the EU Common Fisheries Policy (CFP), had always forced a strategy of recovery of fish stocks (**?**). This recovery reduced the fishing possibilities of the fleets. On that sensea mayor complain from fishing firms was that the stock recovery caused the erosion of their financial profitability.

The above is what we name the *"folk theory"*, that is the profitability erosion resulted from the reduction in fishing possibilities. This theory is not empty of arguments. The implementation of input controls and the lack of efficient economic instruments (i.e., quota transferability) are arguments that from the economic point of view support this theory. Furthermore, while economic theory says that more healthy stocks can increase profitability of the fishing firms, stock size recovery phases are less clear and if we look at the concrete case such as the Galician (north-west of Spain) fleet, the evolution of the profitability is exactly as the one described in the *"folk theory"*: fewer vessels and lower financial profitability.

It is complicate to evaluate this *"folk theory"* in a general way, because EU stock's recoveries (when so) are divided into MS and fleet shares. These shares, defined based on historical catch records coming from the period 1973-1978 (the so-called relative stability principle), have diverged from the fishing capacity of the fleets in such a way that a chronic misalignment of fleet's fishing capacity and their fishing possibilities had been observed, in general, in EU fisheries (**?**).

There are several exceptions to that partitioning of the stock recovery. When Spain and Portugal entered the EU in the year 1986, the so-called southern management stocks were defined. These management stocks, while questionable from the ecosystem point of view, created the possibility to these two MS of managing their own stocks without the compromise of a share that had to be distributed among other MS. Essentially, these two MS were able to take advantage, alone, of the productivity of the southern stocks. Not surprisingly, these stocks have always been in a wrong shape compared to their management objective. This increased the number of biomass recovery programs, echoing the *"folk theory"*.

This was the case of the southern stock of hake recovery plan (**?**), which controlled total allowable catches (TACs) in order to recover the spawning stock of biomass. Other plans for

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this stock aimed to regulate (limit) the maximum number of days at sea per vessel (**?**) to reduce the fishing mortality. But the fleet reacted, adapting their fishing effort and capacity to these plans, and the consequences were that these stocks did not met their management objectives, stagnating *"folk theory"*.

However, given the capacity of these MS to take advantage of the productivity of the stock, without a big compromise in terms of how this productivity has to be shared, creates a relevant analytical framework to evaluate these recoveries policy and furthermore, the fleet behavioral response to this policy, from the fleet's capturing this stock's productivity, point of view.

Given the decentralized fishery policy followed in the EU, single planner frameworks are not appropriated to describe fleet responses (**??**). Therefore, decentralized fisheries models have to be built, where forward looking economic agents react to fisheries management programs based on optimizing individual behavior. This is why in this work we chose a Dynamic Stochastic General Equilibrium (DSGE) model. This model explains aggregate economic phenomena build on explicit micro-foundations involving rational and forward looking optimizing behavior of individual economic agents (**?**). When this model is estimated, policy shocks can be isolated from the historical disturbances that may have affected the economy.

In this work, the estimation of the proposed model allows to assess the effects of the recovery plan boosted by the CFP on the fishery. Furthermore, the estimated model can be used to build counterfactual situations that can be compared to the real impact of the CFP on the fleet. In that sense, a counterfactual scenario is built to analyze what would have happened if a relatively looser recovery policy would have been applied on the rebuilding strategy of the southern hake. In other words, the main aim of this work is to show if *"folk theory"* can be sustained by an economic model or not.

2. Material and methods

2.1. Model

It is assumed that the economy is formed by four types of agents: households, firms, vessels and the regulatory authority that in our context represents the EU.

We consider that regulation acts as a technological constraint that can be embedded in the model by including a lottery in household preferences (**??**). Essentially, instead of choosing the number of fishing days, households choose a probability of fishing. This lottery framework enables the household's preferences to be written as a function of an exogenous parameter z_t that measures how the regulation on the maximum number of days at sea affects to households preferences. We assume that the policy implemented can be summarized by the following stochastic process:

$$z_{t+1} = (1+\gamma)z_t + \varepsilon_{z,t+1},$$

where γ is an exogenous expected trend and $\varepsilon_{z,t+1}$ represents a white noise. Household's welfare is measured in terms of utility. The representative household derives utility from consumption, C_t and desutility from labor, L_t. Income from wages earned, $w_t L_t$, and rental rates of physical capital $R_t K_t$, are used by households to purchase the consumption good and invest, I_t, in productive capital. Formally, the representative household selects its lifetime consumption and labor supply paths by solving the following intertemporal decision problem,

$$\begin{aligned}
\max_{\{C_t,L_t,K_{t+1}\}_{t=0}^{\infty}} \quad & \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \{\log C_t - e^{z_t} B L_t\}, \\
s.t \quad & C_t + I_t = R_t K_t + w_t L_t, \\
& K_{t+1} = (1 - e^{\varepsilon_{\delta,t+1}}\delta)K_t + I_t, \\
& z_{t+1} = (1+\gamma)z_t + \varepsilon_{z,t+1},
\end{aligned}$$

where $\mathbb{E}_t$ represents the expectation given the available information at period t, B is the weight of the labor in terms of consumption, β is the discount factor, δ is the capital depreciation rate and $R_t = r_t + \delta$ is the gross capital rental rate. $\varepsilon_{\delta,t+1}$ is an unexpected shock affecting capital depreciation.

Note that z_t is the policy variable that indirectly regulates the maximum number of days at sea for vessels. Therefore, an unexpected positive (negative) policy shock, $\varepsilon_{z,t+1}$, has to be understood as a reduction on the maximum number of days at sea and that implies an increase (reduction) in household's desutility due to labor.

Firms produce the planned added value of the economy, Y_t, with a Cobb-Douglas technology that uses labor and physical capital as inputs. Formally, firms chooses the input amounts that minimize costs such that:

$$\min_{L_t,K_t} \mathbb{E}_t \{w_t L_t + e^{\varepsilon_{r,t+1}} r_t K_t\} \quad s.t. \quad Y_t \leq A_t K_t^{\alpha} L_t^{1-\alpha},$$

where A_t is the total factor productivity (TFP) and $\varepsilon_{r,t+1}$ represent unexpected shocks affecting the price of physical capital. Note that technology serves to split the added value among the labor and capital income, representing α the capital share of the added value.

On the other hand, vessels select the fishing effort, F_t that allow them to land captures, Y_t^B, compatible with the planned added value. Formally, F_t is selected having into account the **?** capture function, i.e.

$$\begin{aligned}
& \min_{F_t} \left(Y_t^B - Y_t\right)^2 \\
& \qquad s.t.\ Y_t^B = \sum_{a=1}^{A} w_a \frac{p_a F_t}{m + p_a F_t}(N_{a,t} - N_{a+1,t+1}),
\end{aligned}$$

where $N_{a,t}$ represents the fish abundance of age $a = 1....,A$ at time t, w_a p_a are the average weight and the selectivity parameter of age a, respectively, and m is the natural mortality that does not depend on age.

Finally, we assume that the TFP of the economy, A_t, is related with the size of the fishery stock. Formally,

$$A_t = \theta_t \left(\sum_{a=1}^{A} w_a N_{a,t}\right)^{\alpha \text{stock}},$$

Table 1: Bayesian estimation for the Southern Stock of Hake

parameters		prior mean	post. mean	90% HPD interval		prior	pstdev
ρ	(recruitment persistence)	0.900	0.4585	0.2493	0.6182	invg	Inf
α_{stock}	(stock productivity)	0.149	0.8526	0.7199	0.9475	invg	Inf
B	(labor weight)	5.595	3.1238	2.8523	3.4443	invg	Inf
γ	(exogenous trend)	-0.010	-0.2125	-0.3732	-0.0393	norm	0.2000
standard deviation of shocks		prior mean	post. mean	90% HPD interval		prior	pstdev
ε_z	(policy)	0.010	0.1922	0.1455	0.2419	invg	Inf
ε_r	(rental capital)	0.010	0.0060	0.0023	0.0096	invg	Inf
θ	(TFP)	1.000	0.2258	0.1716	0.2727	invg	Inf
ε_δ	(capital depreciation)	0.010	1.3013	0.9460	1.6794	invg	Inf
ε_1	(mortality age 1)	0.010	0.4001	0.3225	0.4748	invg	Inf
ε_2	(mortality age 2)	0.010	0.1057	0.0835	0.1264	invg	Inf
ε_3	(mortality age 3)	0.010	0.3684	0.2979	0.4296	invg	Inf
ε_4	(mortality age 4)	0.010	0.1273	0.0996	0.1550	invg	Inf
ε_5	(mortality age 5)	0.010	0.0857	0.0647	0.1047	invg	Inf
ε_6	(mortality age 6)	0.010	0.1519	0.1137	0.1907	invg	Inf
ε_7	(mortality age 7)	0.010	2.1096	1.4206	2.7207	invg	Inf

invg: Inverse Gamma distribution; norm: Normal distribution

where the parameter θ_t represent TFP shocks due by other factors than those affecting stock abundance and α_{stock} is the TFP elasticity. The biological model is completed with the dynamics of the resource. We consider that the stock evolves according to an age-structured population model where abundance is given by

$$N_{a+1,t+1} = e^{-(m+p_aF_t)+\varepsilon_{a,t+1}} N_{a,t},$$

where $\varepsilon_{a,t+1}$ represents an unexpected shock affecting to the total mortality rate of age a. Note that total mortality rate is decomposed into natural mortality m and fishing mortality, $p_aF_t + \varepsilon_{a,t+1}$, being p_a the selectivity parameter for age a. Moreover, recruitment (in logarithm terms) is modeled as a *1-lag* autoregressive process

$$\log N_{1,t+1} = (1-\rho)\log \overline{N}_1 + \rho \log N_{1,t} + \varepsilon_{1,t+1},$$

where ρ is the autocorrelation parameter and $\overline{N}_1$ is the mean recruitment.

The solution of this DSGE model is solved using standard numerical methods for solving forward looking models with rational expectations based on algorithms that linearizes the system around the steady state (**?**).

2.2. Bayesian estimation

The model is applied to the Galician trawl fleet which is highly dependent on the southern stock of hake (**?**). This fleet operates in the Atlantic Iberian waters (limited in the north-east by the Spanish-French border and in the south-west by the Straits of Gibraltar).

The calibration of the model consists of keeping some parameters fixed and estimating those related to the model dynamics with Bayesian techniques. In particular, we keep fixed parameters from the technology of production: factor shares, α, depreciation of physical capital, δ, and parameters from the Baranov capture equation, p_a and m. We estimate those parameters related to *i)* recruitment dynamics (ρ and the standard deviation of $\varepsilon_{1,t}$), *ii)* abundance dynamics (standard deviations of $\varepsilon_{a,t}$), *iii)* policy dynamics (B, γ and the standard deviation of $\varepsilon_{z,t}$), *iv)* TFP elasticity, α_{stock} and, *v)* capital rental rate (standard deviations of $\varepsilon_{r,t}$).

The biological population data and technological (Baranov) parameters are extracted from **?**. The factor share, α, is set equal to 1/3 following **?** and capital depretation, δ, is selected equal to 12,90% to match fixed capital allowances from **?**.

The Bayesian estimation of ρ, α_{stock}, B and γ (carried out using the software Dynare, see **?**) involves combining the estimation of the parameters by maximum likelihood using an observed set of data with the information obtained from prior distributions defined for those same parameters. The data set used includes yearly observations of abundance for seven ages, N_a for $a = 1, \ldots 7$, landings, Y, labor, L, fishing mortality, F, and physical capital, K. The prior distributions used for the estimation follows the standard practice in DSGE models. In particular, we use as priors the parameters calibrated to match long-run averages, i.e. steady state with $\gamma = 0$.

The biological time series data (1982-2012) refers to the southern stock of hake (*Merluccius merluccius*, coded as HKE). Data were normalized using the sample median. Fishing mortality and landings comes from (**?**). The capital and labour time series (2004-2012) are built using data from Galician Statistics Institute (**?**) and from the Spanish Fishery Economic Survey (**?**).

The steady state of the model was computed assuming a capital output ratio, K/Y, equal to 2 and normalizing labor in 2004 equal to 1/3. Finally we assumed Inverse Gamma prior distributions for non-negative parameters (like the standard deviations of the shock processes) and prior Normal distribution

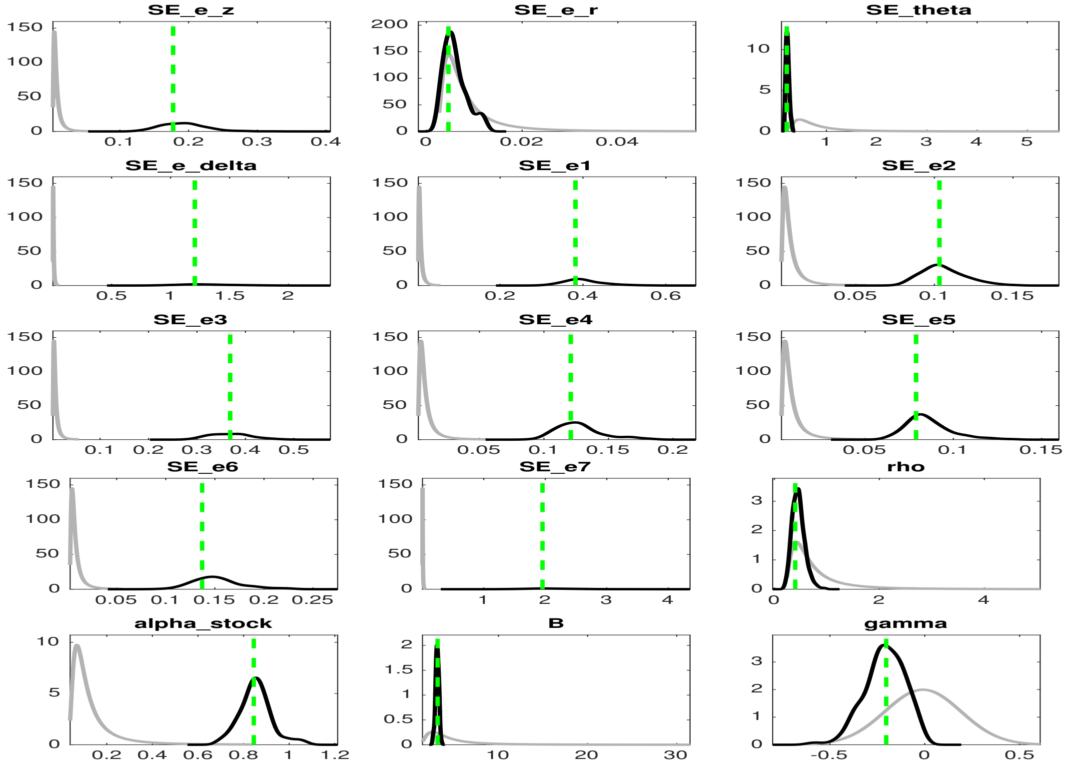

Figure 1: Priors and posteriors. Black (grey) line represents the posterior (prior), green vertical line represents the posterior mode value distribution of the standard deviation of the policy shocks associated with CFP, ε_z, the other (economic and biological) shocks ($\varepsilon_r, \theta, \varepsilon_\delta \, \{\varepsilon_a\}_1^7$) and of the recruitment AR process (ρ), the stock productivity (α_{stock}), the exogenous labor desutility (B) and its trend parameter (γ).

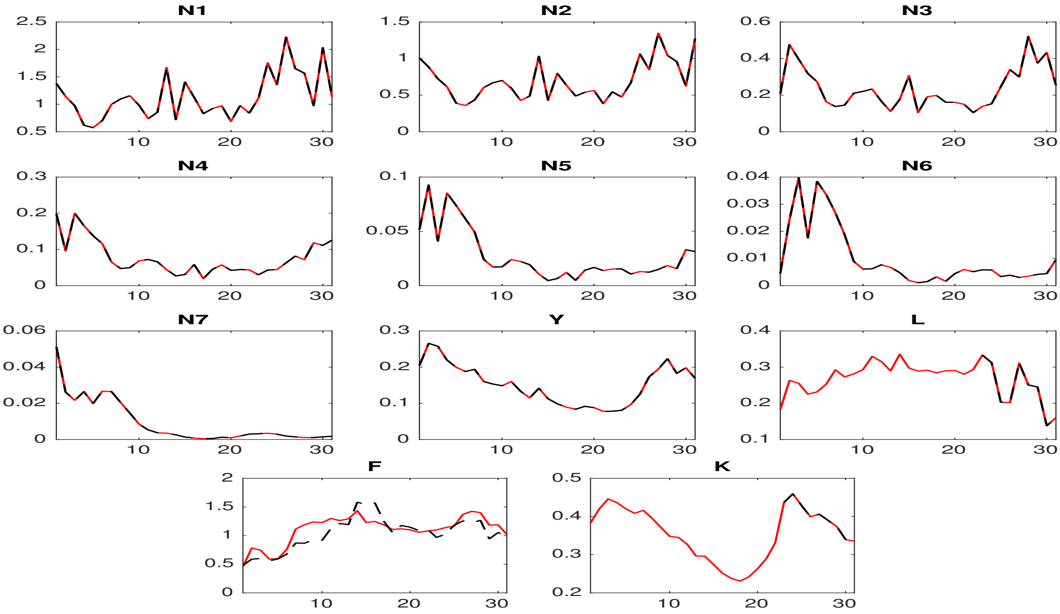

Figure 2: Historical and smoothed variables. The data set used includes yearly observations (1982-2012) of abundance for seven ages, Na for $a = 1, \ldots 7$, landings, Y, labor, L, fishing mortality, F, and physical capital, K. Black (red) line represents the ''true'' (estimated) time series.

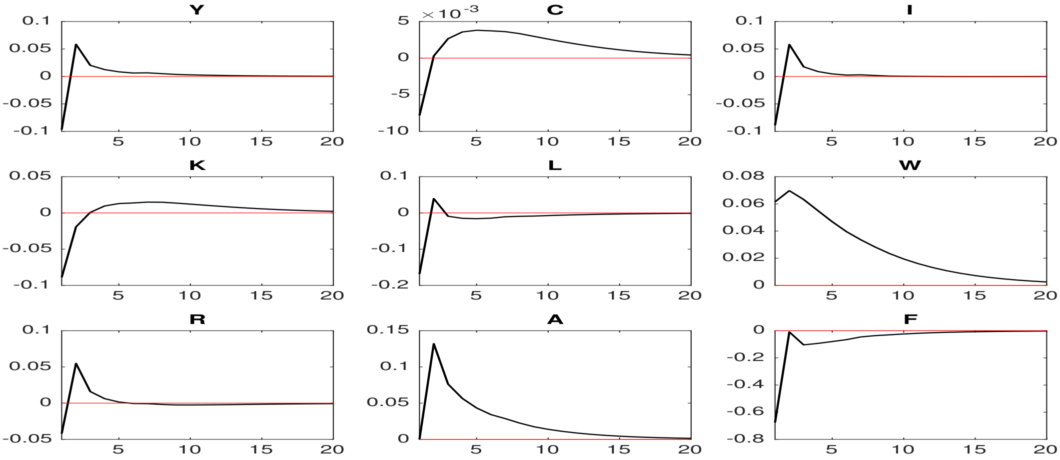

Figure 3: Impulse response function: the fishery's reaction to the impact of a 1% reduction into ε_z on landings, Y, consumption, C, investment, I, physical capital, K, labor, L, wages, W, gross capital rental rate, R, total factor productivity, A, and fishing mortality, F.

for the policy coefficient, γ. Table **??** show the priors and the posterior modes of the main parameters of interest.

Comparing the posterior estimates with the priors is informative. The posterior distributions estimated (black line with the green vertical line representing the posterior modal value) depart substantially from the assumed prior distributions (grey line). Figure **??** shows that priors and posteriors distributions of the stock productivity (α_{stock}), the exogenous labor desutility (B) and its trend parameter (γ), and the recruitment AR process (ρ) present large departures indicating that the information content of the aggregated data is very informative. Figure **??** compares the evolution of the series used (the "true time series) with that generated by the model for the same variables.

In order to understand how the model works in terms of policy, we present the impulse response functions associated to the effects of a policy shock, ε_z. In particular, we study the fishery's reaction to the impact of a 1% reduction into the maximum number of days at sea per vessel. Figure **??** shows that decreasing the maximum number of days at sea per vessel (by increasing z_t with a positive shock in ε_z), as expected, depresses value added, Y_t, consumption, C_t, investment I_t, total employment, L_t, and capital, K_t in the short run. On one hand, the reduction on the hired labor, makes this input more productive leading to an increase on wages. On the other hand, a reduction on the maximum number of days at see drops substantially fishing mortality, F, and this affects positively the abundance of the stock, N_t, for all ages (not shown in the figure). As a result, TFP of the fishery, $A_t = \theta_t \left(\sum_{a=1}^{7} w_a N_{a,t}\right)^{\alpha_{\text{stock}}}$, increases accordingly leading to a substantial recovery of the future added value, consumption, investment and profitability, R_t, of the fishery.

3. Results

The observed evolution of the fleet performance during the period 1982-2012 is the result of two factors: the economic and biological shocks hitting the economy ($S = \varepsilon_r, \theta, \varepsilon_\delta, \{\varepsilon_a\}_1^7$) and the policy shocks associated to the CFP, ε_z. Both elements are inextricably connected and it is not possible to decompose the observable time series as the sum of the two effects (shocks plus policy).

However, it is possible to use the estimated proposed model to measure the effects due to, exclusively, policy shocks by simulating counterfactual situations. In particular, we compare the observed path variables for the period 1982-2012 with the simulated path variables that would have happened under a different policy shocks path.

Formally, let $\{y_t(\varepsilon_{z,t}, \mathbb{S}_t)\}_{t=1982}^{2012}$ represent the path of fishery's observable variables as a function of the policy shocks ε_z and the remaining historical exogenous shocks hitting the fishery, $\mathbb{S}$, for the analyzed period. Lets define now a counterfactual situation with a different path of policy shocks for the period 1986-2005 that represents a 10% increase in the maximum number of days with respect to the original policy, everything else equal, $\{\hat{\varepsilon}_{z,t}\}_{t=1986}^{2012}$. Since an increase in the maximum number of days is given by a negative policy shock, every new period shock is taken as

$$\hat{\varepsilon}_{z,t} = \varepsilon_{z,t} - 0.10 \times \|\varepsilon_{z,t}\|.$$

Note that this counterfactual analysis, considers different policy shocks from 1986 on, that correspond to the period in which the CFP applies to the Galician fleet (Spain entered int he EU in the year 1986).

Once the counterfactual is defined, the estimated model is used to simulate the fishery's variables associated to the alternative policy shocks, $\{y_t(\hat{\varepsilon}_{z,t}, \mathbb{S}_t)\}_{t=1986}^{2012}$. Therefore, by comparing these counterfactual paths, $\{y_t(\hat{\varepsilon}_{z,t}, \mathbb{S}_t)\}_{t=1986}^{2012}$, with the historical ones, $\{y_t(\varepsilon_{z,t}, \mathbb{S}_t)\}_{t=1986}^{2005}$, we can measure how the fishery's variables have been affected exclusively by a policy shock associated to the CFP.

Before investigating the model predictions of the impact of the CFP on the Galician fleet, we highlight the time series obtained from the estimation process for the policy variable, z_t. Figure **??** shows two well defined regimes for the historical path (black paths): before and after 2005 which is the date in

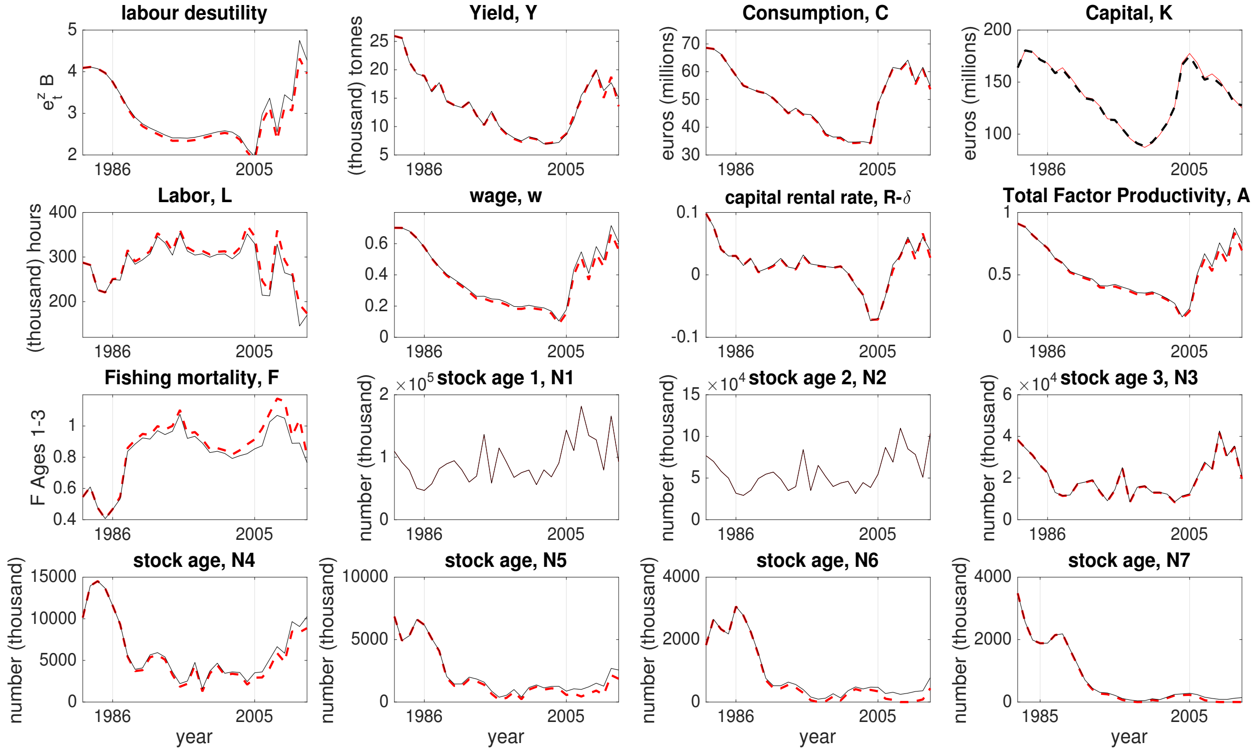

Figure 4: Counterfactual analysis: Red line represents time series associated with a less restrictive policy in the maximum number of days, $\{y_t(\hat{\varepsilon}_{z,t}, \mathbb{S}_t)\}$, and black line represents historical time series, $\{y_t(\varepsilon_{z,t}, \mathbb{S}_t)\}$.

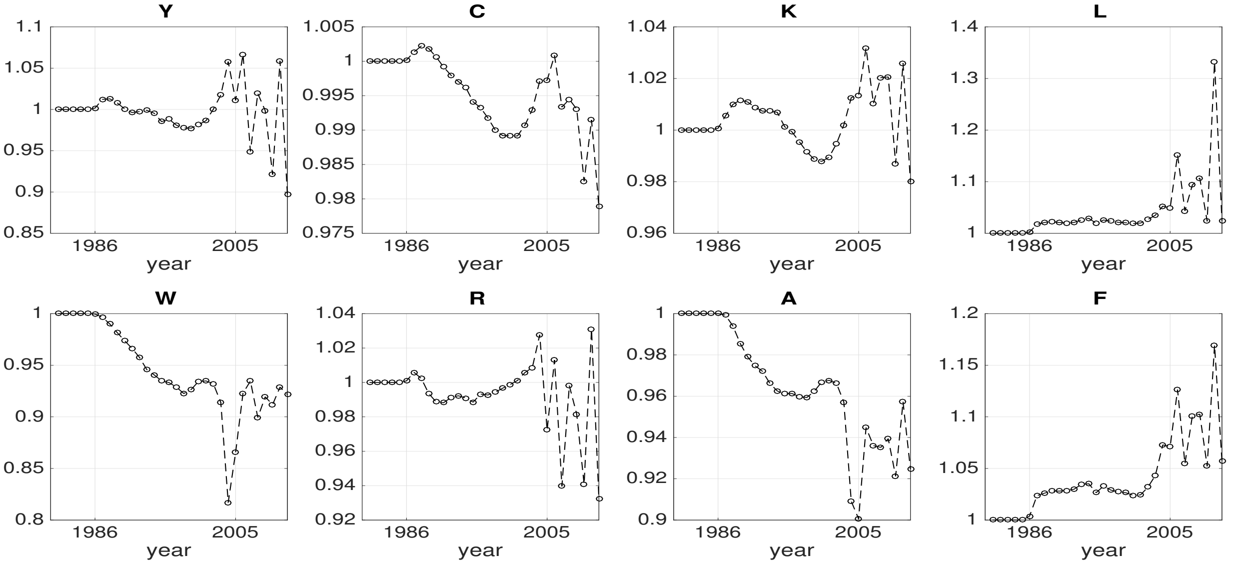

Figure 5: Counterfactual over historical path ratio, $y_t(\hat{\varepsilon}_{z,t}, \mathbb{S}_t)/y_t(\varepsilon_{z,t}, \mathbb{S}_t)$, of landings, Y, consumption, C, physical capital, K, labor, L, wages, W, gross capital rental rate, R, total factor productivity, A, and fishing mortality, F.

which the recovery plan came into effect in the Southern Stock of hake.

Figure **??** illustrates that z_t exhibits a decreasing trend representing a situation compatible with an increase in the total number of days at sea for the period 1986-2005. Along that period, historical policy shocks increased the marginal utility of labor, $e^{z_t}B$, leading to a 50% increase in labor hours, L_t. This increase in the total number of days, affected negatively the stock, decreasing its abundance for all ages, N_a, and the TFP, A. This lower resource productivity generates lower wages, w_t, and rental prices, r_t. As a result, consumption also decreased. Therefore, the estimated model considers that the underlying increase trend in the total number of days at sea between 1986 and 2005, leaded to a deterioration of the financial results of the fleet. These historical paths are consistent with the lack of enforcement of the CFP provided by **?**.

The behavior of the policy variable z_t turn over after 2005, when the recovery plan started. Paths displayed in Figure **??** are compatible with an increase in the total number of days at sea (i.e with a decreasing trend of z_t) from 2005 on. This reduced the marginal utility of labor, $e^{z_t}B$, and as result total labor hours, L_t decreased dramatically. This decreasing trend of the total number of days, affected positively the stock, increasing abundance for all ages, N_a, and TFP, A. The higher resource productivity generated higher wages, w_t, and rental prices, r_t. As a result, consumption increased. Therefore, the estimated model consider that the decreasing trend in total number of days between 2005 and 2012 improved the financial results of the fleet.

The historical and counterfactual fleet behavior are compared by computing the ratio

$$\frac{y_t(\hat{\varepsilon}_{z,t}, \mathbb{S}_t)}{y_t(\varepsilon_{z,t}, \mathbb{S}_t)}.$$

The counterfactual value is higher (lower) than the historical value when the ratio is higher (lower) than 1. Figure **??** displays this ratio for all the variables. Our counterfactual analysis shows that a policy equivalent to increase 10% the maximum number of days at sea would have increased the labor hours (L) and in fishing mortality, (F_t), for the whole period 1986-2012 and it would have reduced wages (w), TFP (A) and consumption (C). Patterns are not so clear when production (Y), capital (K), rental price of capital (r) are analyzed. Table **??** shows the average counterfactual ratios of all the variables.

Summarizing, the counterfactual analysis shows that relaxing the enforcement of the CFP during the period 1986-2012 would have worsened the economic results of the fleet by lowering wages and rental price of capital, in average, 6.79% and 0.88%, respectively. Economic agents would be affected negatively since labor would be increased 4.87% and consumption would be reduced 0.59%. Also the resource would have suffered the looser policy increasing the fishing mortality 5.02% and reducing the TFP 4.37%

4. Discussion and conclusions

Economic modeling literature addressing management of renewable resource under uncertainty (**???**) was criticized by biological modelers for their inadequate treatment of realistic biological dynamics and uncertainties. As a result, in practice, fisheries management government agencies manage fish stocks by the advice provided using biological models based on simulation methods (**??**).

Table 2: Counterfactual Effects Ratio

Variable	Ratio (%) $\frac{y_t(\hat{\varepsilon}_{z,t},\mathbb{S}_t)}{y_t(\varepsilon_{z,t}),\mathbb{S}_t)} \times 100$
Output (Y)	99.60
Consumption (C)	99.41
Capital (K)	100.46
Labor (L)	104.87
Wages (w)	93.11
Rental Price (r)	99.11
TFP (A)	95.63
Fishing Mortality (F)	105.03

After **?** showed that age-structured fishery models representing single planners were analytically tractable, optimization methods have been introduced in biological models to assess fisheries (**???????????**).

In this work this optimization view of fisheries models is extended to a DSGE approach. In particular, a DSGE model is used to build a decentralized fishery where rational and forward looking economic agents react to fisheries management programs. Using bayesian methods the model is estimated to assess the impact of the CFP on the economic performance of the Galician trawl fleet fishing the southern stock of hake. This approach complements previous studies that also had analyzed the performance of this fishery in the context of the CFP regulations (**????**).

From the policy point of view, the main advantage of the DSGE approach presented here is that once the model is estimated, counterfactual situations can be simulated. This enables the policy shocks to be isolated from the historical disturbances that may have affected the economy. This is the main reason why DSGE models, with a special emphasis on bayesian methods, have become the main tool for policy analysis at central banks (**????**). Our study takes advantage of this feature to address fisheries policy issues with this methodological approach.

Did the CFP reduced the economic performance of the Galician fleet? This is not a simple question. The implicit pessimistic view on the question is supported by studies that analyze the CFP under dimensions so diverse as the restrictions on the tradeability of quotas, (**?**), the stakeholder engagement (**?**), the lack of considering unobserved genetic diversity (**?**) or the use of moratorium as management tool (**?**). In this diverse context, our study focus on the impact of the CFP on the productivity of the fleet to answer the question. We obtain that, when we take into account an endogenous productivity, if a looser CFP had been implemented during the period 1986-2012, the income obtained by the owners of the vessels and crews would not have increased. That is, we show how the *"folk theory"* it is not necesarilly met in this ilustration.

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