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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 Atlantic 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 labour 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%.

1. Introduction

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

EU fisheries historically failed to maintain healthy stocks and in reducing overcapacity (Villasante, 2010). This was probably due to the lack of an efficient institutional framework. However, a strong commitment on MSY objectives set by the EU Common Fisheries Policy (CFP) always forced a strategy of recovery of fish stocks (Cardinale et al., 2013). This recovery reduced the fishing possibilities of fleets. In that regard, a mayor complaint from fishing firms was that the stock recovery decreased their financial profitability.

The above is what is known as the *"folk theory"*: It holds that the decrease in profitability resulted from the reduction in fishing possibilities. This theory is not devoid of arguments. The implementation of input controls and the lack of efficient economic instruments (i.e. quota transferability) are arguments that support this theory from the economic point of view. Furthermore, economic theory says that more healthy stocks can increase the profitability of fishing firms, but stock size recovery phases are less clear and a look at specific case such as the Galician fleet (north-west Spain) reveals that the trend of historical profitability is exactly like that described in the *"folk theory"*: Fewer vessels and lower financial profitability.

It is complicated to assess this *"folk theory"* in a general way, because EU stock recoveries (if any) are divided into MS and fleet shares. These shares, defined on basis of historical catch records 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 come to be observed, in general, in EU fisheries (Da Rocha and Gutiérrez, 2006).

There are several exceptions to that partitioning of the stock

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recovery. When Spain and Portugal entered what is now the EU in 1986, the so-called southern management stocks were defined. These management stocks, while questionable from the ecosystem point of view, gave these two MS the possibility of managing their own stocks without committing to 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 diverged from their management objective. This increased the number of biomass recovery programs, echoing the *"folk theory"*.

This was the case of the recovery plan for the EU Atlantic southern stock of hake (EU, 2005), which controlled total allowable catches (TACs) in order to recover the spawning stock of biomass. Other plans for this stock aimed to regulate (limit) the maximum number of days at sea per vessel (EU, 2017) to reduce the fishing mortality. But the fleet reacted by adapting their fishing effort and capacity to these plans, and the consequences were that these stocks failed to meet their management objectives and stagnated *"folk theory"*.

However, given the capacity of these MS to take advantage of the productivity of the stock without no major commitment in terms of how that productivity had to be shared, a relevant analytical framework was set up for assessing this recovery policy and the way in which fleets responded to it from the point of view of the productivity.

Given the decentralized fishery policy followed in the EU, single planner frameworks are not appropriate for describing fleet responses (Da Rocha and Gutiérrez, 2012; Da Rocha et al., 2017). Therefore, decentralized fishery models have to be built where forward-looking economic agents react to fishery management programs based on optimizing individual behaviour. This is why in this paper we have chosen a Dynamic Stochastic General Equilibrium (DSGE) model. This framework enables aggregate economic phenomena to be built on explicit micro-foundations involving rational and forward looking optimizing behaviour of individual economic agents (Kydland and Prescott, 1982). When this type of models are estimated, policy shocks can be isolated from historical disturbances that may have affected the economy. To the best of our knowledge, this is the first time this methodology is used to assess policies in fisheries economics.

In this paper, the estimation of the proposed model enables the effects on the fishery of the recovery plan implemented by the CFP to be assessed. Furthermore, the model estimated 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 up to analyse what would have happened if a relatively looser recovery policy had been applied in the EU Atlantic southern stock of hake rebuilding strategy. In other words, the main aim of this paper is to show whether or not *"folk theory"* can be sustained by an economic model.

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, which in our context is 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 (Hansen, 1985; Rogerson, 1988). Essentially, instead of choosing the number of fishing days, households choose a probability of fishing. This lottery framework enables the preferences of household to be written as a function of an exogenous parameter z_t that measures how regulating the maximum number of days at sea affects household 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 welfare is measured in terms of utility. The representative household derives utility from consumption, C_t, and disutility from labour, L_t. Income from wages earned, $w_t L_t$, and rental rates on 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 labour supply paths by solving the following intertemporal decision problem,

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

where $\mathbb{E}_t$ represents the expectation given the information available at period t, B is the weight of labour 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, $\varepsilon_{z,t+1}$, must be understood as a reduction in the maximum number of days at sea, which implies an increase (reduction) in household disutility due to labour.

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

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

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

Vessels select the fishing effort, F_t that enables them to land catches, Y_t^B, compatible with the planned added value. Formally, F_t is selected taking into account the Baranov (1918) catch function, i.e.

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

where $N_{a,t}$ represents the abundance fish 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, which, we assume, that it does not depend on age.

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

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

where the parameter θ_t represents TFP shocks due to factors other 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

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

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

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

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

This DSGE model is solved using standard numerical methods for solving forward-looking models with rational expectations. The solving method is based on a linear state-space form obtained by linearizing the system around the steady state (Blanchard and Kahn, 1980).

2.2. Bayesian estimation

The model is applied to the Galician trawl fleet which is highly dependent on the EU Atlantic southern stock of hake (Sampedro et al., 2016). This fleet operates in the Iberian Atlantic waters (limited to the north-east by the Spanish-French border and to the south-west by the Straits of Gibraltar). Galicia is the main Spanish and EU region from the economic dependency on fisheries, point of view (Macho et al., 2013).

The model calibration keeps some parameters fixed and estimates those related to the model dynamics using Bayesian techniques. In particular, we keep fixed parameters for the technology of production: factor shares, α, depreciation of physical capital, δ, and parameters from the Baranov catch equation, w_a, 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 taken from STECF (2015). The factor share, α, is set to 1/3 following Gollin (2002) and capital depreciation, δ, is selected at 12.90% to match fixed capital allowances from MAPAMA, Ministerio de Agricultura, Pesca y Alimentación (2016b).

The Bayesian estimation of ρ, α_{stock}, B and γ, carried out using Dynare software (Collard, 2001), 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, labour, 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 the parameters calibrated to match long-run averages as priors, i.e. steady state with $\gamma = 0$.

The biological time series data (1982–2012) refers to the EU Atlantic southern stock of hake (*Merluccius merluccius*, coded as HKE). Data is normalized using the sample median. Fishing mortality and landings comes from ICES (2017). The capital and labour time series (2004–2012) are built using data from the Galician Statistics Institute (IGE, Instituto Galego de Estatística) and from the Spanish Economic Survey of Fisheries (MAPAMA, Ministerio de Agricultura, Pesca y Alimentación, 2016a).

The steady state of the model is computed assuming a capital output ratio, K/Y, of 2 and normalizing labour in 2004 at 1/3. Finally, we assume Inverse Gamma prior distributions for non-negative parameters (like the standard deviations of the shock processes) and prior normal distribution for the policy coefficient, γ. Table 1 shows the priors and the posterior (mean and standard deviation) of the main parameters of interest.

Comparing the posterior estimates with the priors is informative. Fig. 1 shows the prior and posterior distributions of the estimated variables. The posterior distributions estimated (the black line, with the vertical green line representing the posterior modal value) depart substantially from the prior distributions assumed (grey line). In particular, the prior and posterior distributions of stock productivity (α_{stock}), exogenous labour disutility (B) and its trend parameter (γ), and the recruitment AR process (ρ) differ substantially, indicating that the information content of the aggregated data is very informative. Fig. 2 compares the evolution of the series used (the "true" time series) with that generated by the model for the same variables.

To understand how the model works in terms of policy, we present the impulse response functions associated with 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. Fig. 3 shows that, as expected, decreasing the maximum number of days at sea per vessel (by increasing z_t with a positive shock in ε_z) 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 in the hired labour makes this input more productive, leading to an increase on wages. On the other hand, a reduction in the maximum number of days at sea substantially decreases fishing mortality, F, and this positively affects the abundance of the stock, N_t, for all ages (not shown in the figure). As a result, TFP of the fishery, $A_t = \theta_t(\sum_{a=1}^{7} w_a N_{a,t})^{\alpha_{\text{stock}}}$, increases accordingly leading to a substantial recovery in the future added value, consumption, investment, and profitability, R_t, of the fishery.

3. Results

The evolution of fleet performance in the period 1982–2012 observed is the result of two factors: the economic and biological shocks hitting the economy ($\mathbb{S} = \varepsilon_r, \theta, \varepsilon_\delta, \{\varepsilon_a\}_1^7$) and the policy shocks associated with the CFP, ε_z. The two 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 proposed model estimated to measure the effects due exclusively to 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 arisen under a different policy shocks path.

Formally, let $\{y_t(\varepsilon_{z,t}, \mathbb{S}_t)\}_{t=1982}^{2012}$ represent the path of the 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 period analysed. Now define 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, with all else being, $\{\hat{\varepsilon}_{z,t}\}_{t=1986}^{2012}$. Given that 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, which correspond to the period in which the CFP applies to the Galician fleet (Spain joined the European Community in the year 1986).

Once the counterfactual situation is defined, the model estimated is used to simulate the fishery variables associated with the alternative policy shocks. 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 are affected exclusively by a policy shock associated with the CFP.

Before investigating the predictions of the model concerning the impact of the CFP on the Galician fleet, it is worth highlighting the time series obtained from the estimation process for the policy variable, z_t. Fig. 4 shows two well defined regimes for the historical path (black paths): before and after 2005, which is when the recovery plan came into effect for the EU Atlantic southern stock of hake.

Fig. 4 illustrates that z_t shows a decreasing trend representing a situation compatible with an increase in the total number of days at sea for 1986–2005. During that period, historical policy shocks increased the marginal utility of labour, $e^{z_t}B$, leading to a 50% increase in labour hours, L_t. This increase in the total number of days affected the stock negatively, decreasing its abundance for all ages, N_a, and the TFP. This lower resource productivity led to lower wages, w_t, and rental prices, r_t. As a result, consumption also decreased. Therefore, the model estimated considers that the underlying increasing trend in the total number of days at sea between 1986 and 2005 led to a deterioration in the financial results of the fleet. These historical paths are consistent

Table 1
Bayesian estimation for the EU Atlantic southern stock of hake.

		prior mean	post. mean	90% HPD interval		prior dist	pstdev
parameters							
ρ	(recruitment persistence)	0.900	0.4585	0.2493	0.6182	invg	0.1193
α_{stock}	(stock productivity)	0.149	0.8526	0.7199	0.9475	invg	0.0700
B	(labour weight)	5.595	3.1238	2.8523	3.4443	invg	0.1893
γ	(exogenous trend)	−0.010	−0.2125	−0.3732	−0.0393	norm	0.1052
standard deviation of shocks							
ε_z	(policy)	0.010	0.1922	0.1455	0.2419	invg	0.0323
ε_r	(rental capital)	0.010	0.0060	0.0023	0.0096	invg	0.0024
θ	(TFP)	1.000	0.2258	0.1716	0.2727	invg	0.0321
ε_δ	(capital depreciation)	0.010	1.3013	0.9460	1.6794	invg	0.2282
ε_1	(mortality age 1)	0.010	0.4001	0.3225	0.4748	invg	0.0473
ε_2	(mortality age 2)	0.010	0.1057	0.0835	0.1264	invg	0.0128
ε_3	(mortality age 3)	0.010	0.3684	0.2979	0.4296	invg	0.0414
ε_4	(mortality age 4)	0.010	0.1273	0.0996	0.1550	invg	0.0179
ε_5	(mortality age 5)	0.010	0.0857	0.0647	0.1047	invg	0.0127
ε_6	(mortality age 6)	0.010	0.1519	0.1137	0.1907	invg	0.0245
ε_7	(mortality age 7)	0.010	2.1096	1.4206	2.7207	invg	0.4265

invg: Inverse Gamma distribution; norm: Normal distribution; pststd: Posteriors' standard deviation.

with the lack of enforcement of the CFP evidenced by Da Rocha et al. (2012a).

The behaviour of the policy variable z_t changed after 2005, when the recovery plan started. The paths shown in Fig. 4 are compatible with an increase in the total number of days at sea (i.e with a decreasing trend of z_t) from 2005 onwards. This reduced the marginal utility of labour, $e^{z_t}B$, and as result total labour hours, L_t decreased dramatically. This decreasing trend in the total number of days affected the stock positively, increasing abundance for all ages, N_a, and TFP. The higher resource productivity led to higher wages, w_t, and rental prices, r_t. As a result, consumption increased. Therefore, the model estimated considers 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 behaviour were compared by computing the ratio:

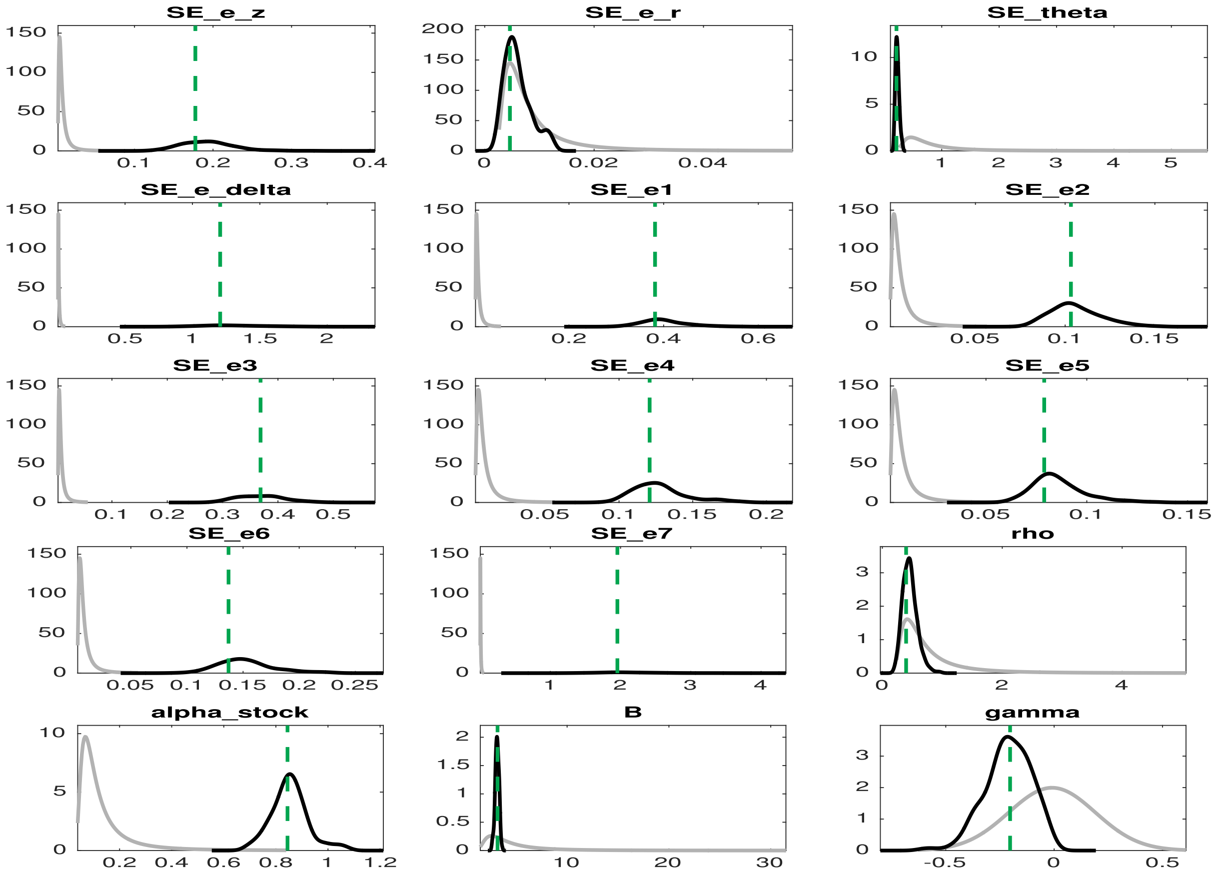

Fig. 1. Priors and posteriors. The black (grey) line represents the posterior (prior), the vertical green line represents the posterior mode value distribution of the standard deviation of the policy shocks associated with CFP, ε_z, the other (economic and biological) shocks (ε_r, θ, $\varepsilon_\delta\{\varepsilon_a\}_1^7$) and of the recruitment AR process (ρ), the stock productivity (α_{stock}), the exogenous labour disutility (B) and its trend parameter (γ). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

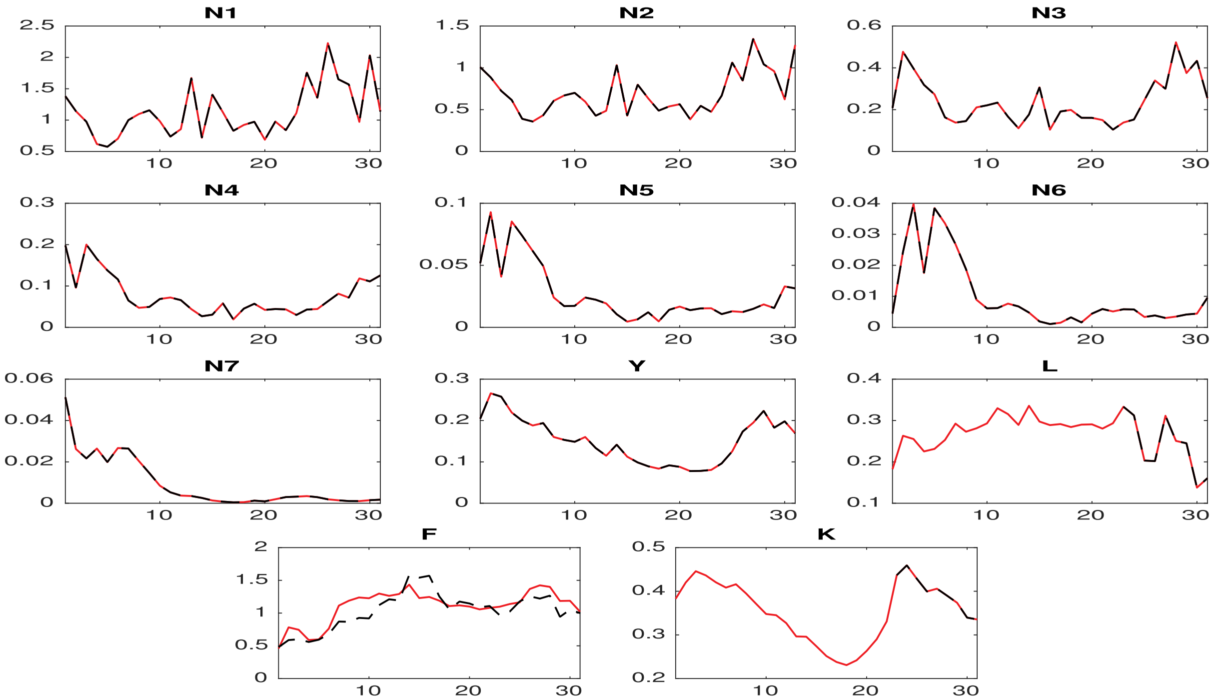

Fig. 2. Historical and smoothed variables. The data set used includes yearly observations (1982–2012) of abundance for seven ages, *Na* for $a = 1, \ldots 7$, landings, *Y*, labour, *L*, fishing mortality, *F*, and physical capital, *K*. The black (red) line represents the "true" (estimated) time series. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

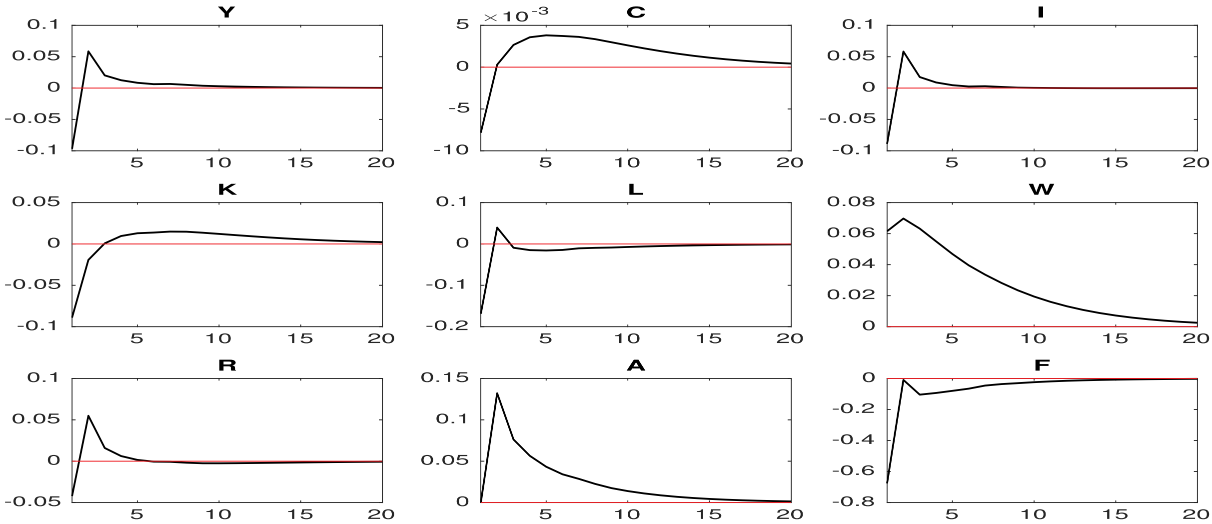

Fig. 3. Impulse response function: the fishery's reaction to the impact of a 1% reduction in ε_z on landings, *Y*, consumption, *C*, investment, *I*, physical capital, *K*, labour, *L*, wages, *W*, gross capital rental rate, *R*, total factor productivity, *A*, and fishing mortality, *F*.

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

The counterfactual value is higher (lower) than the historical value when the ratio is higher (lower) than 1. Fig. 5 shows this ratio for all the variables. Our counterfactual analysis shows that a policy equivalent to an increase of 10% in the maximum number of days at sea would have increased labour hours (*L*) and fishing mortality, (F_t), for the whole period 1986–2012 and it would have reduced wages (*w*), TFP (*A*) and consumption (*C*). The patterns are not so clear when production (*Y*), capital (*K*), and the rental price of capital, (*r*), are analysed. Table 2 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 by 6.79% and the rental price of capital by 0.88%, on average. Economic agents would have been affected negatively since labour would have increased by 4.87% and consumption would have fallen by 0.59%. Also, the resource would have suffered from the looser policy, with fishing mortality increasing by 5.02% and the TFP falling by 4.37%.

4. Discussion and conclusions

Economic modelling literature addressing the management of renewable resource under uncertainty (Reed, 1979; Clark and Kirkwood, 1986; Sethi et al., 2005) has been criticized by biological modelers for its inadequate treatment of realistic biological dynamics and uncertainties. As a result, in practice, government fishery management

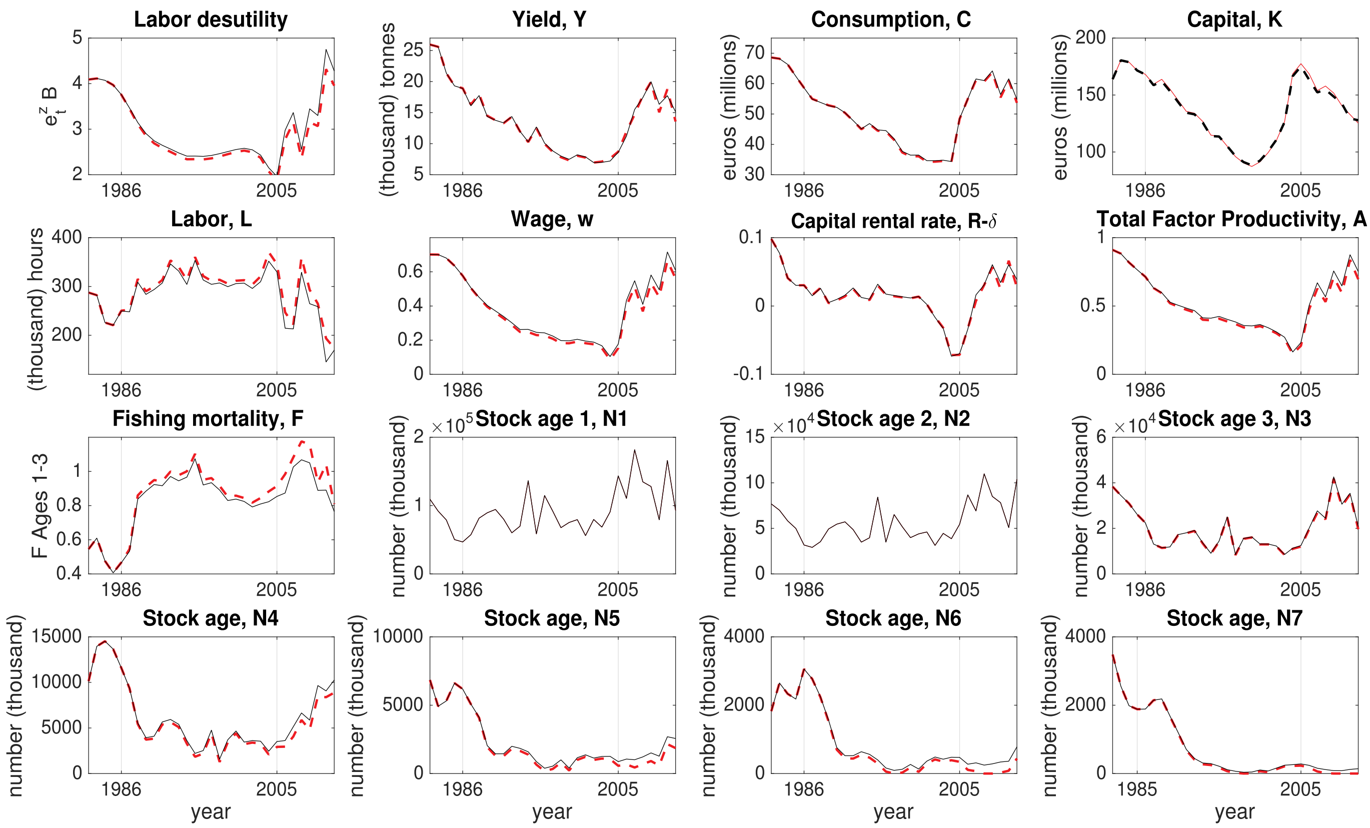

Fig. 4. Counterfactual analysis: The red line represents time series associated with a less restrictive policy in the maximum number of days, $\{y_t(\hat{\varepsilon}_{z,t}, \mathbb{S}_t)\}$, and the black line represents historical time series, $\{y_t(\varepsilon_{z,t}, \mathbb{S}_t)\}$. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

agencies manage fish stocks based on the advice provided by using biological models based on simulation methods (Ulrich et al., 2012; Nielsen et al., 2018).

After Tahvonen (2009) showed that age-structured fishery models representing single planners were analytically tractable, optimization methods began to be introduced into biological models for assessing fisheries (Grafton et al., 2007; Groger et al., 2007; Dichmont et al., 2010; Da Rocha et al., 2010; Da Rocha and Gutiérrez, 2011; Da Rocha et al., 2012c,b; 2013, 2016; Voss et al., 2011; Froese and Quaas, 2012).

This paper extends this optimization view of age-structured fishery models to a DSGE approach, although other types of stock dynamics (biomass models) can also be incorporated. In particular, a DSGE model

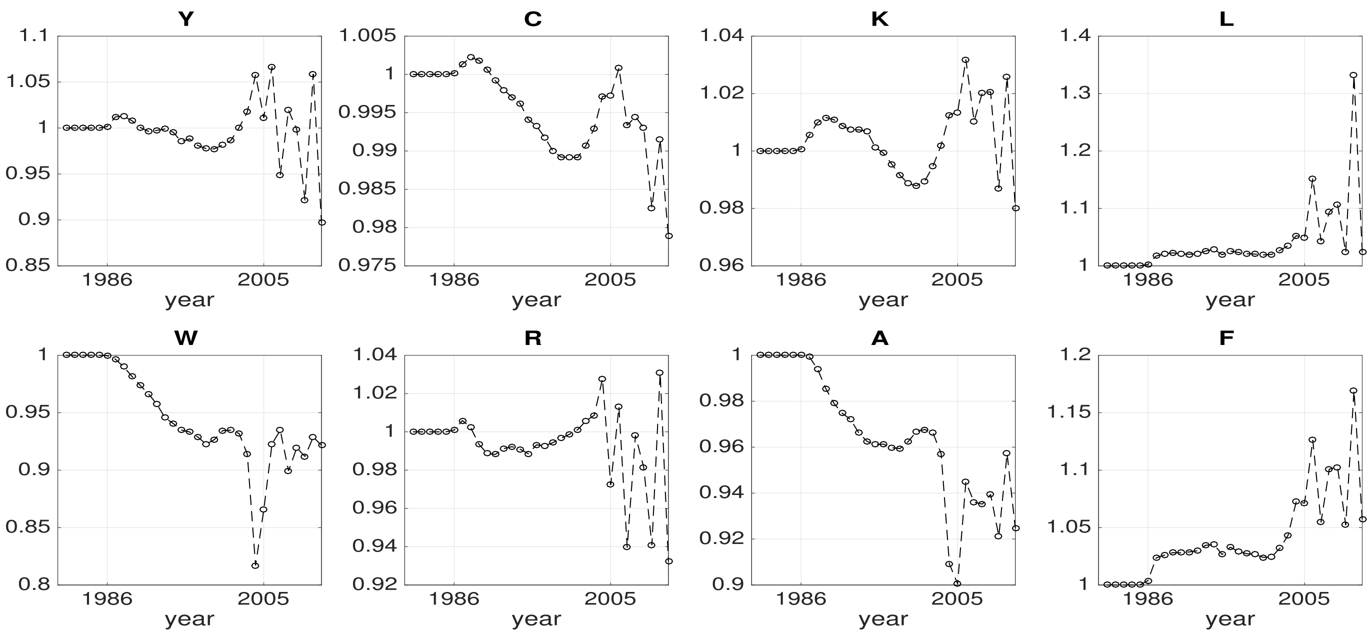

Fig. 5. Counterfactual over historical path ratio, $y_t(\hat{\varepsilon}_{z,t}, \mathbb{S}_t)/y_t(\varepsilon_{z,t}, \mathbb{S}_t)$, of landings, *Y*, consumption, *C*, physical capital, *K*, labour, *L*, wages, *W*, gross capital rental rate, *R*, total factor productivity, *A*, and fishing mortality,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

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
Labour (L)	104.87
Wages (w)	93.11
Rental Price (r)	99.11
TFP (A)	95.63
Fishing Mortality (F)	105.03

is used to build a decentralized fishery where rational and forward-looking economic agents react to fishery 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 EU Atlantic southern stock of hake. This approach complements previous studies that also analysed the performance of this fishery in the context of CFP regulations (Caballero-Miguez et al., 2008; Antelo et al., 2012; García et al., 2016; Varela-Lafuente et al., in press, 2019).

From a computational point of view, the estimation procedure in Dynare is highly efficient. In less than 3 min Dynare computes, the linear state-space form of the model, the likelihood density of the model using the linear state-space form and a Kalman Filter forecasting procedure and the posterior distribution using Markov Chain Monte Carlo methods (Metropolis-Hastings algorithm).[1] In addition, the computational time of the counterfactual analysis –done by simulating the linear state-space form of the model using a Matlab perturbation routine– is less than 6 s.

From a policy point of view, the main advantage of the DSGE approach is that once the model is estimated, counterfactual situations can be simulated. This enables the policy shocks to be isolated from historical disturbances that may have affected the economy. This is the main reason why DSGE models, with special emphasis on Bayesian estimation methods, have become the main tool for policy analysis at central banks (Christiano et al., 2005; Smets and Wouters, 2007; Andrés et al., 2010; Fernández-Villaverde et al., 2016). Our study takes advantage of this feature to address fishery policy issues using the same methodological approach.

Did the CFP reduced the economic performance of the Galician fleet? This is not an easy question to answer. The pessimistic view implicit in the question is supported by studies that analyse the CFP under perspectives ranging from restrictions on the tradability of quotas, (Garza-Gil and Varela-Lafuente, 2015), stakeholder engagement (Sampedro et al., 2016), the lack of considering unobserved genetic diversity (Villasante, 2012), the use of moratoriums as a management tool (Garza-Gil et al., 2011), the existing gap between recommended and implemented TACs (Carpenter et al., 2016b) to, in general, the political will to achieve sustainable fisheries (Carpenter et al., 2016a). In this diverse context, our study focuses on the impact of the CFP on the productivity of the fleet in order to answer the question. We find that, when endogenous productivity is taken into account, if a looser CFP had been implemented in 1986–2012 the income obtained by the owners of the vessels and crews would not have increased, i.e. we show that the *"folk theory"* is not necessarily borne out in this illustration.

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[1] Using a MacBook Air (13 inches, beginning of 2015), with a 2,2 GHz Intel Core i7 processor OS X El Capitan 10.11.6 (15G1108).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2018.10.013.

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