Policy Analysis for Fisheries: A Dynamic CGE Approach*

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ABSTRACT
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The purpose of this paper is to contribute to and facilitate the use of dynamic CGE model for fisheries policy and decision-making. A dynamic open-economy model is presented, in which the linkage between economy-ecology-biology is integrated in a regional CGE approach. To understand economic, ecological and biological relationships we present different CGE approaches.
The practical suitability of the specification is illustrated in an empirical application. To the best of our knowledge, this is the first application of a dynamic CGE model applied to fishery sector as a function of economic, ecological and biological constraints.

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I. INTRODUCTION

General equilibrium (GE) theory suggests that real-world markets are interdependent where changes in supply or demand conditions usually have repercussions on supply and demand conditions. Since the beginning of the 1980s GE models have become popular to analyse and describe economy, because they provide quantitative results in policy analysis. General equilibrium models are increasingly being used for many problems (see Harberger, 1962; Shoven and Whalley, 1992). They may be applied to any large economic change. Computable general equilibrium (CGE) model is a policy model where the main goal is to formulate a model of simultaneous equilibrium[1].

In this paper, we focus on a dynamic CGE model. We give a brief introduction to CGE modelling, and we provide a simple basic structure that can be used for the development of a CGE model for fisheries. The main goal of this study is to develop a CGE model for the evaluation of the socio-economic contributions of the fishing activities. From fishery management point of view, it is necessary to employ a regional economic model and estimate the regional economic impacts attributable to fishery policies. For our simple example we consider real data from Salerno, Italy. Our regional model is the first CGE model applied to fisheries, where the link between economics-ecology and biology is discussed and presented.

The paper is organised as follows: Section II provides the data (SAM) from Salerno-Italy, while Section III presents the general structure of a CGE model. Section IV presents the CGE model statement, while in Section V we discuss the application of a CGE model to fisheries. Section VI presents the main empirical results for Salerno obtained using GAMS[2] software package (www.gams.com). Finally, Section VII concludes the paper and proposes future research.

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[1] The simplest form of general equilibrium model is the input-output model developed by Leontief.

[2] GAMS (*G*eneral *A*lgebraic *M*odelling *S*ystem) is an optimisation software. Other software package similar to GAMS is GEMPACK.

II. THE SOCIAL ACCOUNTING MATRIX

CGE modelling takes the following steps: (i) database construction, (ii) model estimation and calibration, (iii) base run solutions and (iv) simulations, i.e. solving the model under different scenarios (for CGE steps see Appendix 3).

Social Accounting Matrices (SAMs) provide a general framework for representing the flow of resources within an economy in a given period of time – usually a year. Input-output analysis was first implemented at a national level in the United States in 1936 by Wassily Leontief and has since come to play a central role in economic analysis and national income accounting throughout the world (see Leontief, 1986). The first official input-output tables for the United Kingdom were published in 1961 for the year 1954, and tables have since been published at regular intervals. Input output methods have been particularly influential in the analysis of regional economies (see, e.g. Armstrong & Taylor, 2000). Regions of the United Kingdom have, however, been rather poorly served in terms of coverage by reliable and accurate input-output accounts. Social Accounting Matrices add to input-output accounts, among other things, greater detail on the distribution and uses of income in the economy. In a SAM, the economy is conceived as being made up of a number of broad areas such as intermediate production, households, government, capital, trade, and the labour market. The SAM then gives a detailed record of the flow of resources within and between each of these areas.

Social Accounting Matrices add to input-output accounts, among other things, greater detail on the distribution and uses of income in the economy. The income accounts of the SAM record the flow of production resources into households, in the form of wages and salaries paid to employees, dividends paid to shareholders *etc*. At the same time, the household account of the SAM shows what households paid to producers to purchase finished goods and services. A typical SAM will identify a number of different household types by employment status, number of dependants, social class and other such characteristics. Both production and household sectors have relationships with government through taxation, subsidy, transfer payments and government consumption. The SAM is thus extended across the broad areas of the economy. Our SAM distinguishes the following accounts: activities, commodities, factors, households, savings, taxes and the rest of the world. Activity column entries indicate expenditures incurred during the production process and include purchases of intermediate inputs and payments to the factors of production. The total supply of commodities, value at market prices, is given as domestic marketed production, imports of goods and non-factor services, indirect taxes as well as export taxes. The commodity row gives the total demand for marketed commodities and includes household and government consumption. The intersection between the commodity column and government row gives the indirect taxes paid. Furthermore, factors include labour and capital. The factor account pays factor taxes to the government and factor payments to the RoW. Household column indicates the allocation of total household income among income taxes and savings.

In addition, the savings-investment column gives the total investment expenditure in the economy, while the RoW column shows the exports of goods and services. Purchases of imports and receipts of factor payments are specified in the row.

In general, the SAM provides a snapshot of the economy at a single point in time and each cell records the value of each transaction (i.e. the product of prices and quantities).

Appendix 1 shows an example of a SAM structure used in a general CGE model.

III. OVERVIEW OF THE CGE MODEL

- *CGE General Structure*

In this section we present the general structure of a simple CGE model. In general equilibrium theory we formulate a model of simultaneous equilibrium in competitive markets for all commodities. The model explains all payments based on the SAM. In the standard CGE models, one first distinguishes between different producers, goods and factors. According to the theory, producers maximise profits, while consumers maximise utility. In this type of model, equilibrium is then characterised by a set of prices and levels of production (i.e. market demand equals supply for all commodities). The model is based on a system of simultaneous equations, in which factors are fully utilized (see Dervis, de Melo and Robinson, 1982; Robinson, 1990 for more details). Prices are set so that equilibrium profits of firms are zero. Factor incomes are divided among households (total household income is used to pay taxes, save and consume), while government revenue comes from direct and indirect taxes. Household incomes equal household expenditures (equilibrium condition). Household goods consumption is determined by assumptions about consumer behaviour.

Consumers are generally assumed to maximize utility, where the assumed form of the utility is a CES, a Linear expenditure system or a Translog function. Furthermore, government tax revenues equal government expenditures including subsidy payments. The Rest of the World supplies imports and demands export goods. This section gives an overview of the basic CGE model by explaining all the payments that are recorded in our SAM.

CGE models are based on the Walrasian general equilibrium structure (Walras, 1954). Accordingly, "*for any price vector, the value of the excess demand is identically zero*". For production, we have two types: Cobb-Douglas (CD) and Constant Elasticity of substitution (CES). If the production function has no constant returns of scale, we can calculate the different supply functions. The model satisfies Walras law in that the set of commodity market equilibrium conditions is functionally dependent.

In most CGE models, imports are determined by an import demand function. CGE models employ the "*Armington assumption*" that products produced in different regions are different from each other in quality (Armington, 1969). Armington has three advantages: (i) it accounts for the large amount of cross-hauling present in the data (imports and exports), (ii) it explains the empirical observation clear, and (iii) it allows for differing degrees of substitution among different products and goods. Furthermore, exports of a good depend on the ratio of the domestic price of the good and the export price of the good. There is a distinction between domestically supplied goods and exported goods according to a constant elasticity of transformation (CET) function.

To run a CGE model, we estimate a number of parameters from the model, so that the equilibrium solution satisfies all our equations under the method of "calibration". Because CGE models contain so many parameters to be estimated, the only way is to use the estimation method called calibration. Calibration for CGE models can be used in order to estimate parameters in, for example, Cobb-Douglas, CES and CET functions. In addition, we need information of prices, quantities and values in the initial equilibrium for model estimation. For instance, we can set all the prices at unity at the initial equilibrium condition (homogeneity of degree zero). Figure 1 presents the structure of a production technology when specified by a CES. Figure 2 shows the structure of a simple model of one country, 2 producing sectors and 3 goods (imports, M; domestic production, D; and exports, E). For general CGE steps see Appendix 3.

Figure 1. Production technology

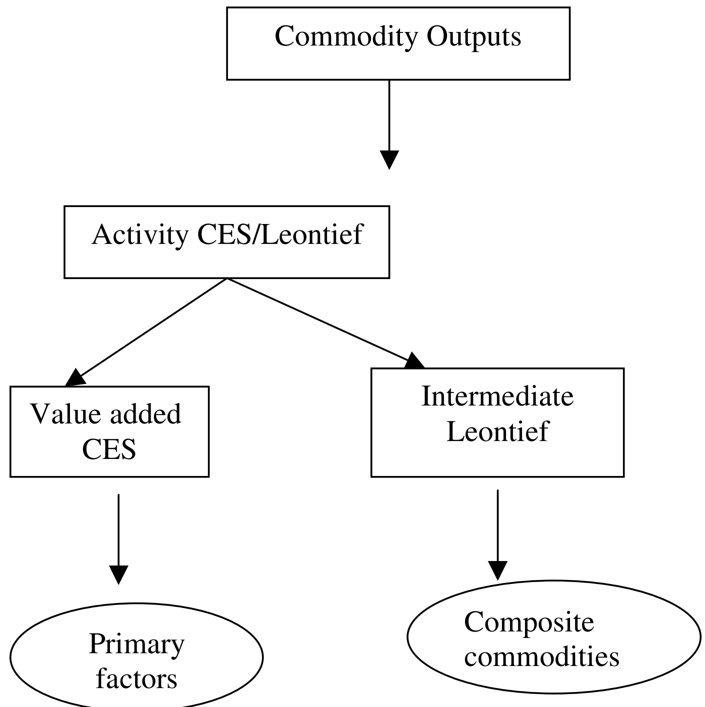
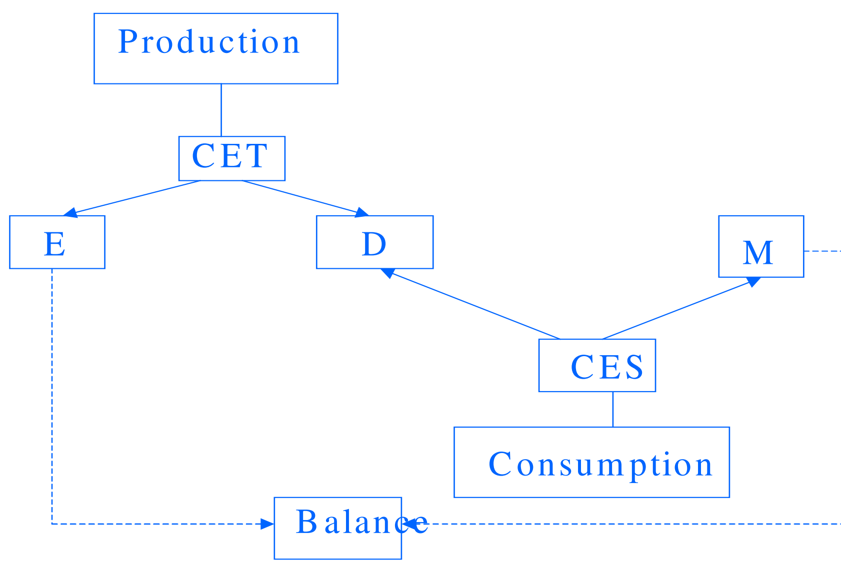


Figure 2. Structure of a simple (basic) model



- **A Dynamic Model for Fisheries**

Following Hartwick and Olewiler (1986), the equilibrium in fisheries may have a number of assumptions. One can use most common forms of markets in economic analysis: perfect competition (open access) and monopoly. In open access, time value in the form of the discount rate is set to infinity. This is done regarding the fact that a fisherman on the open sea has no reason to leave anything to the future. He harvests as much as he is able to catch. When we do care about the steady state, we mean that harvest = natural growth. This comes from the stock of fish, which maximises the total economic surplus. Furthermore, the stock changes the profit prospects of the fishermen. In equilibrium, the marginal value of changing the fish stock should be equal to what can be earned from the royalty on the capital market. A stable income over time obviously presumes a stable fish stock.

On the other hand, we also need information about the growth of the species. For most fish species we assume that the growth rate of the stock depends on its size or biomass. As the biomass or stock size increases, the growth rate will decline. Graphically, each point on the growth curve represents a sustainable yield of fish for a given stock of fish. We define a biological equilibrium as the value of the fish stock for which there is no growth in the fish population or biomass

Furthermore, to get an idea about a system out of balance between harvest and natural growth we have to turn to dynamic analysis. We assume that disequilibrium affects the decisions of our factors in the economy and causes adaptive behaviour. The main question in fisheries is "what will be the reaction of the fishermen upon decreasing stocks or fish?".

IV. CGE MODEL STATEMENT

In this section we present the variables and equations for a dynamic CGE model (Lofgren *et al.*, 2001). A dynamic CGE model deals with issues of next periods. The variables are divided into four parts: prices, production, institutions and system constraints (see Table 1). The equations (mathematical statement of the model) are presented in more details in Appendix 4.

Table 1. CGE Variables and Equations

VARIABLES	EQUATIONS
Import price	= tariff adjustment*exchange rate*import price
Export price	= tariff adjustment * exchange rate * export price
Absorption	=(domestic sales price*domestic sales quantity)+(import price*import quantity)*(sales tax adjustment)
Domestic Output Value	(producer price*domestic output quantity) = (domestic sales price*domestic sales quantity) + (export price*export quantity)
Activity Price	= (producer prices) * yields
Value-added Price	= (activity price) – (input cost per activity unit)
Activity Production Funct.	= f (factor inputs)
Factor Demand	(Marginal cost of factor f in activity a) = (marginal revenue product of factor f in activity a)
Intermediate demand	= f (activity level)
Output function	Domestic output = f (activity level)
Armington Function	Composite supply = f (import quantity, domestic use of domestic output)
Import-Domestic Demand Ratio	= f (domestic-import price ratio)
Composite supply for nonimported commodities	= domestic use of domestic output
CET Function	Domestic output = f (export quantity, domestic use of domestic output)
Export-Domestic Supply Ratio	= f (export-domestic price ratio)
Output Transformation for NonexportedCommodities	Domestic Output = domestic sales of domestic output
Factor Income	Household factor income = (income share to household h)* (factor income)
Household income	= (factor incomes) + (transfers from government) *ROW

Household Consumption Demand for commodity c	= f (household income, composite price)
Investment Demand for commodity c	= (base-year investment) * (adjustment factor)
Government Revenue	= (direct taxes) + (transfers from ROW)+ (sales tax) + (import tariffs) + (export taxes)
Government Expenditures	(Government spending) = (household transfers) + (government consumption)
Factor Markets	(Demand for factor f) = (supply of factor f)
Composite Commodity Markets	(Composite supply) = (composite demand, sum of intermediate, household, government, investment demand)
Savings-Investment Balance	(Household savings) +(government savings)+(foreign savings)=(investment spending)+(WALRAS dummy variable)

V. DYNAMIC CGE MODEL FOR FISHERIES

Applied literature focusing on general equilibrium effect on fisheries is small. However, many previous studies of regional economic impacts of fishery used Input-Output (I-O) models. We have three main categories in the literature: commercial fishing, sport fishing and those that deals with both. Studies in the first category include King and Shellhammer (1981) and Butcher et al. (1981). Furthermore, Martin (1987) and Hammel *et al*. (2002) explain sport fishing, while Hushak *et al*. (1986) and Carter and Radtke (1986) show the impact of fishery dealing with the third category.

Computable General Equilibrium (CGE) Models for Fisheries is not a widely area of research. With an applied CGE model we can take into account the fish population dynamics. To our knowledge, only one CGE model of this type exists, the recent study of Houston *et al.* (1997). They develop a regional CGE model to evaluate the impacts associated with reduced marine harvests for a coastal Oregon region. They use five fishing sectors or vessel types, groundfish trawlers, crabbers, shrimp and scallop draggers, whiting midwater trawlers and small boats. The Oregon model has five processing sectors, 24 aggregated industry and commodity sectors, household income categories, two government expenditures, three factor income accounts and an investment expenditure account. Appendix 2 shows an example of a SAM structure for fisheries used in and proposed by Houshak *et al*. (1997).

Houston *et al*. (1997) present three scenarios for Oregon CGE model. According to the first scenario, there is a 20% reduction in groundfish catch because the fishery has become less productive and/or more restrictive. Under this scenario, boats catch less per unit fishing effort. Under the second scenario, there is a $6 million buyback of 16 trawl boats. It is assumed that this money comes from the federal government, or some other source outside the local economy. Finally, the third scenario assumes a removal of 16 trawl boats. Under the three policy scenarios, Houston *et al*. (1997) estimate changes in numbers of jobs (i.e. employment impacts of reduced groundfish harvests). The results show a bigger change (effect) on scenario 1.

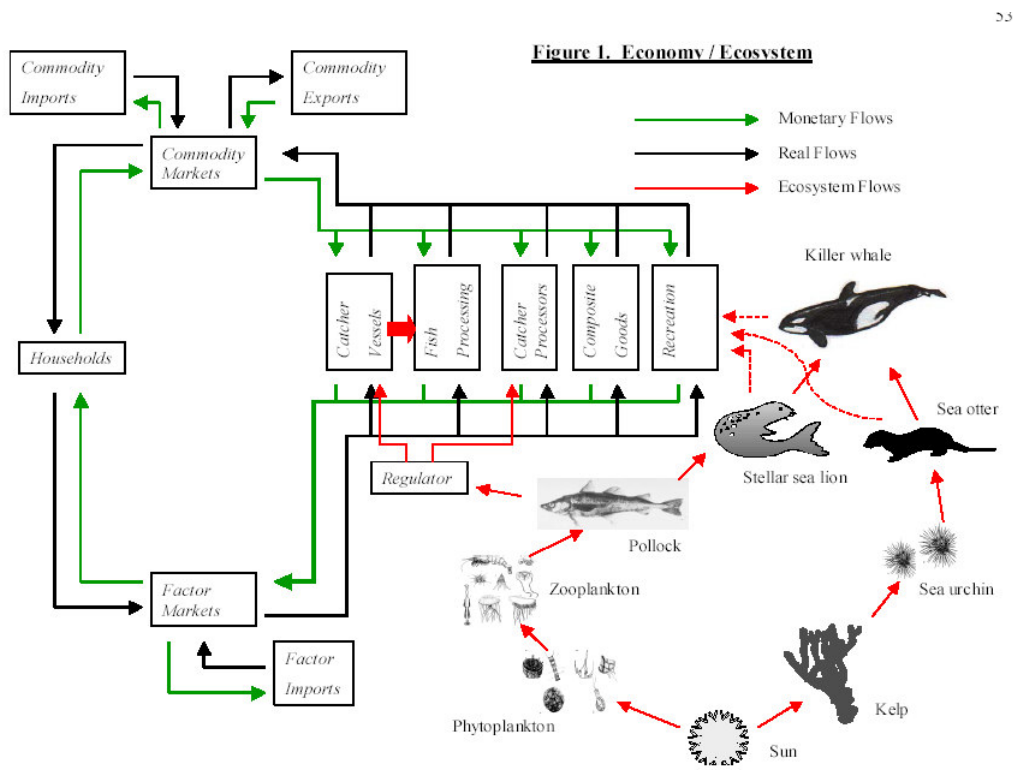
Our model is different than that of Houston *et al*. (1997) because we are looking at the linkage between biology, ecology and economics.

- **Linking Economy and Ecology**

For the link between economy and ecology, Finnoff and Tschirhart (2004) link dynamic economic and ecological CGE models (Figure 1). They focus on the approach for multiple species in complex food webs. The ecosystem model is combined with a CGE model of an economy. The model is applied to Alaska and eight species marine ecosystem. The analysis focuses on the fact that ecosystem affects economy and economy affects ecosystem, and both systems are general in equilibrium. Their model shows how ecosystem externalities can be measured. Jin *et al*. (2003) develop and present a methodological approach that links economy-ecology by merging an input-output model of a coastal economy with a model of a marine food web. They also present a numerical example based on the linear system sub-models of the economy and ecosystem, for the New England region. They simulate the economic impacts of changes in primary production in the ecosystem on final demands for fishery products. The results illustrate the effects of incorporating the impacts of habitat destruction and ecosystem structure on resource multipliers.

Furthermore, for solving ecological-economic models Duraiappah (2001) explains the complexities which arise when ecological and economic systems are integrated using GAMS. The paper presents the steps and solution of nonlinear IEE models that can be used for policy analysis and prescription.

Next we present the CGE model for Salerno (Salerno-CGE model).



(Source: Finnoff & Tschirhart, 2004)

VI. THE SALERNO-CGE MODEL & RESULTS

The Computable general equilibrium model for Salerno is a dynamic model of the Salerno economy calibrated to 2001 (for obvious reasons we can’t present the full Salerno-SAM here). The structure of the Salerno CGE model is as follows: the Salerno-CGE model is disaggregated into two Households (fisheries and non-fisheries), two Factors (labor and capital), two Firms, 29 Activities, 37 Commodities, Government, 6 Taxes, Savings and the Rest-of-the-World (RoW).

Our regional model has two components: a CGE model, which represents the behaviour of economic agents (i.e. economic part), and a biology model, which is a representation of biological process affecting fisheries productivity (under the biological production functions for Salerno).

The economic part of CGE model for Salerno employs standard assumptions. The model assumes that producers maximize profits subject to production functions, while households maximize utility subject to budget constraints. Production and consumption behaviour are modelled using the constant elasticity of substitution (CES) family of functions, which includes Leontief[3], Cobb-Douglas and constant elasticity of transformation (CET) functions. Hence, substitution between regional supply and exports is given by CET, while firms smoothly substitute over primary factors through CES functions. Furthermore, factors are mobile across activities, available in fixed supplies, and demanded by producers at market-clearing prices. The model satisfies Walras' law in that the set of commodity market equilibrium conditions is functionally dependent, while the model is homogeneous of degree of zero in prices. Other main assumptions are the following two: first, the Salerno is treated as an open economy, implying that Salerno faces exogenous prices for imports and exports. Second, products are differentiated according to region and Armington assumption, so that imports and exports are different from domestically produced goods.

Regarding the Savings, its row receives payments from the household, while its column shows spending on commodities for investment. We assume that (i) household income is allocated in fixed shares to savings and consumption, (ii) the value of total investment spending is determined by the value of savings and (iii) investment spending is allocated by the commodities. Here, the set of equilibrium conditions includes the commodity market equilibrium conditions as well as the savings-investment balance (including the Walras variable). Note that if the CGE model works, then Walras should be zero. Furthermore, the government of the model earns its revenues from income and sales taxes and spends it on consumption and transfers to households. Government savings is the difference between its revenues and spending. The income tax is a fixed share of the gross income of each household.sales taxes are fixed shares of producer commodity prices. The government consumes commodity quantities, and pays market prices and taxes. The final account of our model is the rest of the world (RoW).

- **Explanation for the biological production functions for the Salerno case.**

Economic analysis of fishery management policies require the evaluation of economic impacts of changes in *biological* and *economic* conditions of fishery. The biological production functions are included in the Salerno-CGE Model through the equation:

$$(1) \qquad B_{t+1} = B_t + g(B_t) - Y_t \left(1 + \gamma \times \left(\frac{Y_t}{B_t} \right)^{\beta - 1} \right)$$

$$\text{with } \gamma = \frac{1-\alpha}{\alpha} \times \frac{B^{curr}}{Y_{in}^{curr}}$$

where B is the biomass of the stock, t is the time step in the model (year), g is the growth function of the stock (equation 2), Y is the yield estimated in the economic sub-module of the CGE Model, γ is a constant parameter and β is the reactivity parameter. $Y_{in,\ curr}$ represents the Salerno catch (=Y_{curr}/α).

Growth function

For the Salerno case, the biologic functions of growth g(B) can either be in the form of a Pella and Tomlinson (generalized production model) with 3 parameters r, K, m, either in the form of a Fox model (exponential model) with only 2 parameters. In this case, the parameter value of m is one but the equation is different. All the stocks with a m value of one in table I follow a Fox model whereas the others follow a Pella and Tomlinson model.

The growth in the Fox model:

$$(2) \qquad g(B) = r \times B \times \ln\left(\frac{K}{B} \right)$$

[3] For all sectors, we assume Leontief technology, that is, that a fixed input quantity is needed per unit

The growth in the Pella and Tomlinson model:

$$g(B) = r\,B\left(1-\left(\frac{B}{K}\right)^{m-1}\right) \qquad (3)$$

Values of reactivity β

Two values of β can be first tested in the Salerno case:

- β=1 corresponds to the fact that a variation in the fishing effort of the Salerno fleet (increase for instance) will be followed by the same reaction of the other fleets targeting the same stock (increase). This assumes that the biological production function of Salerno matches exactly the production function of the whole stock but only represents the relative part a of the fishing mortality (and yield).

- β=0 corresponds to the situation in which the fishing effort of other fleets applied on a given stock remain constant, whatever the variations of effort of Salerno (assumption often made in bio-economic models).

To solve equation (1) we assume that $B_{t+1} - B_t < \varepsilon$ (=0.0001). So, we get that

$$g(B_t) = (B_{t+1} - B_t) + Y_t((1+\gamma\times\left(\frac{Y_t}{B_t}\right)^{\beta-1})$$

Table I. Population parameters estimated for the stocks selected for the Salerno case.

Scientific name	Sub-areas	r	K (Tons)	m
Aristaemorpha foliacea	G5 operational unit	-0.38	25	0.295
Aristeus antennatus	G5 operational unit	-0.30	10	0.137
Engraulis encrasicolus	Sardinia	0.84	75794	1
Merluccius merluccius	G5 operational unit	-0.70	500	0.555
Mullus barbatus	G5 operational unit	-0.38	150	0.201
Mullus surmuletus	Sardinia	0.2	2433	1
Nephrops norvegicus	Sardinia	0.18	15163	1
Octopus vulgaris	Sardinia	0.25	38441	1
Others	Sardinia	0.4	338063	1
Parapaeneus longirostris	G5 operational unit	-0.34	50	0.329
Sardina pilchardus	Sardinia	0.22	296426	1
Sepia officinalis	Sardinia	0.25	1207	1
Squilla mantis	Sardinia	1.41	1902	1
Thunnus thynnus	East Atl. & Mediterranean	0.36	297271	1

of output.

Table II. Exploitation parameters estimated for the stocks selected for the Salerno case (Y curr represents the total catch).

Scientific name	Sub-areas	F curr	Ycurr	B curr
Thunnus thynnus	G5 operational unit area	0.72	28959	40282
Sepia officinalis	G5 operational unit area	0.47	322	690
Octopus vulgaris	Sardinia	0.39	3158	8130
Aristaemorpha foliacea	G5 operational unit area	0.48	3.5	15
Aristeus antennatus	G5 operational unit area	0.66	1.9	6
Parapaeneus longirostris	Sardinia	1.02	9.2	20
Mullus barbatus	Sardinia	1.46	29.2	48
Squilla mantis	Sardinia	3.90	465	119
Engraulis encrasicolus	Sardinia	3.02	6414	2127
Merluccius merluccius	G5 operational unit area	0.93	57	131
Nephrops norvegicus	Sardinia	0.55	387	704
Sardina pilchardus	Sardinia	0.78	6575	8379
Mullus surmuletus	Sardinia	0.2	179	895
Others	East Atl. & Mediterranean	0.4	49747	124366

Table III. Relative proportion of Salerno catch in the total catch for each stock (α)

Scientific name	Sub-areas	Salerno relative part
Aristaemorpha foliacea	G5 operational unit	100%
Aristeus antennatus	G5 operational unit	100%
Engraulis encrasicolus	Sardinia	3%
Merluccius merluccius	G5 operational unit	100%
Mullus barbatus	G5 operational unit	100%
Mullus surmuletus	Sardinia	3%
Nephrops norvegicus	Sardinia	100%
Octopus vulgaris	Sardinia	6%
Others	Sardinia	5%
Parapaeneus longirostris	G5 operational unit	100%
Sardina pilchardus	Sardinia	2%
Sepia officinalis	Sardinia	24%
Squilla mantis	Sardinia	34%
Thunnus thynnus	East Atl. & Mediterranean	9%

- **RESULTS FOR SALERNO CASE**

We run our CGE model for Salerno using the optimisation software package GAMS (www.gams.com). A CGE model in GAMS has seven parts:

1. Sets definition
2. data input (SAM)
3. initial values from the Sam

4. calibration for estimation
5. variables and equations definitions
6. initial values and numeraire
7. Solution

The steps for the equilibrium solution between economic and biological modules are presented in Appendix 5.

Table IV and Table V show the main results from Pella-Tomlinson model and Fox model respectively. Our results based on the equations (1), (2) and (3) for the Salerno case. First, we estimate the parameters of surplus production models in the form of Pella-Tomlinson and Fox models. After, the biological production function through the yield from the CGE economic model is estimated in order to take into account for the reactivity of fleets regarding a variation in the Italian fishing effort targeting a given group. Two different scenarios of reactivity are considered, namely: beta = 1 and beta = 0.

TABLE IV. **Pella-Tomlinson model for Salerno case**

Yield	382	64	882	147
Scientific Name	Aristeus antennatus	Merluccius	Mullus barbatus	Parapaeneus longirostris
SAM name	Blue & Red shrimp	Europ. Hake	Stripped Mullet	Deepwater Rose shrimp
CGE name	gsb-c	eh-c	sm-c	drs-c
R	-0.3	-0.7	-0.38	-0.34
K	10	500	150	50
M	0.137	0.555	0.201	0.329
B	6	131	48	20
g	0.9972287	74.72757	27.09253	5.77554
Alpha	1	1	1	1
Y_{curr}	1.9	57	29.2	9.2
$Y_{in,curr}$	1.9	57	29.2	9.2
Gama	0	0	0	0
$B_{(t+1)}$	-375.00277	141.7276	-806.907	-121.224
M*F	0.09042	0.51615	0.29346	0.33558

TABLE V. **Fox model for Salerno case**

Yield	637	39	456	745	11923	68	745	172	19287
Scient. name	Engraulis	Mullus sur	Nephrops	Octopus	Others	Sardina	Sepia offic	Squilla mant	Thunnus
SAM name	Eur. Anchovy	Red mullet	Norw. Lobster	Com. Octopus	Others	Eur. Pilchard	Com. Cuttlefi	Spottail Man	Norw. Bluefin tuna
CGE name	an-c	rm-c	nl-c	co-c	os-c	ep-c	cc-c	sms-c	bt-c
r	0.84	0.2	0.18	0.25	0.4	0.22	0.25	1.41	0.36
K	75794	2433	15163	38441	338063	296426	1207	1902	297271
m	1	1	1	1	1	1	1	1	1
B	2127	895	704	8130	124366	8379	690	119	40282
g	6384.35543	179.0101	389.0095131	3157.618169	49746.57	6573.6203	96.4622801	465.036319	28984.76
alpha	0.03	0.03	1	0.06	0.05	0.02	0.24	0.34	0.09
Ycurr	6414	179	387	3158	49747	6575	322	465	28959
$Y_{in,curr}$	213800	5966.667	387	52633.33333	994940	328750	1341.66667	1367.64706	321766.7
gama	0.32166978	4.85	0	2.419949335	2.374971	1.2488852	1.62857143	0.16890323	1.265811
Bt+1/beta=0	7190.164	-3305.74	637.0095	-9131.57	-133176	4420.211	-1082.25	391.9368	-1009.64
Bt+1/beta=1	7669.452	845.8601	637.0095	8739.756	133872.8	14799.7	-1171.82	382.985	25566.06
g(bt)/beta=0	704.9	984.8	456.0	5386.3	82714.1	176.2	3344.9	179.4	53246.5
g(Bt)/beta=1	841.9	228.2	456.0	2547.9	40239.8	152.9	1958.3	201.1	43700.7

VII. SUMMARY

A fishery consists of a number of different fishing activities and characteristics, including the types of fish to be harvested and the types of vessels and gear use. There may be many species of fish being harvested by a variety of different vessels.

Fisheries market is the subject of increasing interest to many people around the world. To project the impact of changes in demand and supply, and of other structural or policy changes, on the fisheries market a regional model is required. In this paper we provide a review of a Computable General Equilibrium Model (CGE) with application to the fishing industry of Salerno in Italy. Our CGE model is one of the first regional CGE models for fisheries, which distinguishes between different species and identifies fisheries by region.

To examine possible differential impacts on individual fishing sectors, we disaggregate sectors into separate harvesting sectors and processing sectors. In addition to that, other sectors and categories are presented through the Social Accounting Matrix (SAM) of Salerno.

Furthermore, our general equilibrium model takes into account two main parts: the economic one (i.e. economic production functions) and the biological production functions in order to estimate the CGE and take into account for the reactivity of fleets regarding a variation in the Italian fishing effort targeting a given group. To do so, we consider two different biological scenarios based on the Pella-Tomlinson and Fox models.

Our results show the link between economics and biology in terms of equilibrium conditions. Two different scenarios of reactivity are considered in order to illustrate the potential range of responses of the stock to fishing exploitation. These scenarios are the following: (i) foreign fleets exactly follow the variation in effort allocation of the Italian fleet, and (ii) foreign fleets do not modify their fishing effort. In addition, we report the link between economy and ecology.

In this report, we do not discuss any economic simulation scenarios. Our main objective is to provide the link between economy-ecology and biology, and show how we can present it in the static form of a CGE model under the optimisation software package GAMS. The next step is to make simulations of a dynamic CGE model for fisheries under economy-ecology-biology links. Since, the dynamics of fishery is very important for economic analysis, it is necessary to answer the questions “how is dynamic equilibrium reached?” and “will dynamic equilibrium reached?”.

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APPENDIX 1: REGIONAL SOCIAL ACCOUNTING MATRIX (SAM)

Structure of a Regional Social Accounting Matrix

	Industry	**Commodity**	**Labor**	**Capital**	**Household**	**Government**	**S-I**	**ROW**
Industry		Gross Output (Make Matrix)						
Comm.	Intermediate Input Use (Use Matrix)				Household Purchase	Government Purchase	Investment	Exports
Labor	Labor Factor Income							
Capital	Capital Factor Income							
Household			Resident Labor Income	Resident Capital Income		Transfer to Household		
Government	Indirect Business Tax			Corporate tax & Property tax	Personal Income Tax	Transfer to Government		
S-I				Depreciation & Retained Earnings	Household Savings	Government Savings		
ROW		Imports	Labor Income Leakage	Capital Income Leakage			- (External Savings)	

Note: 1. S-I denotes savings-investment
2. ROW denotes rest of the world

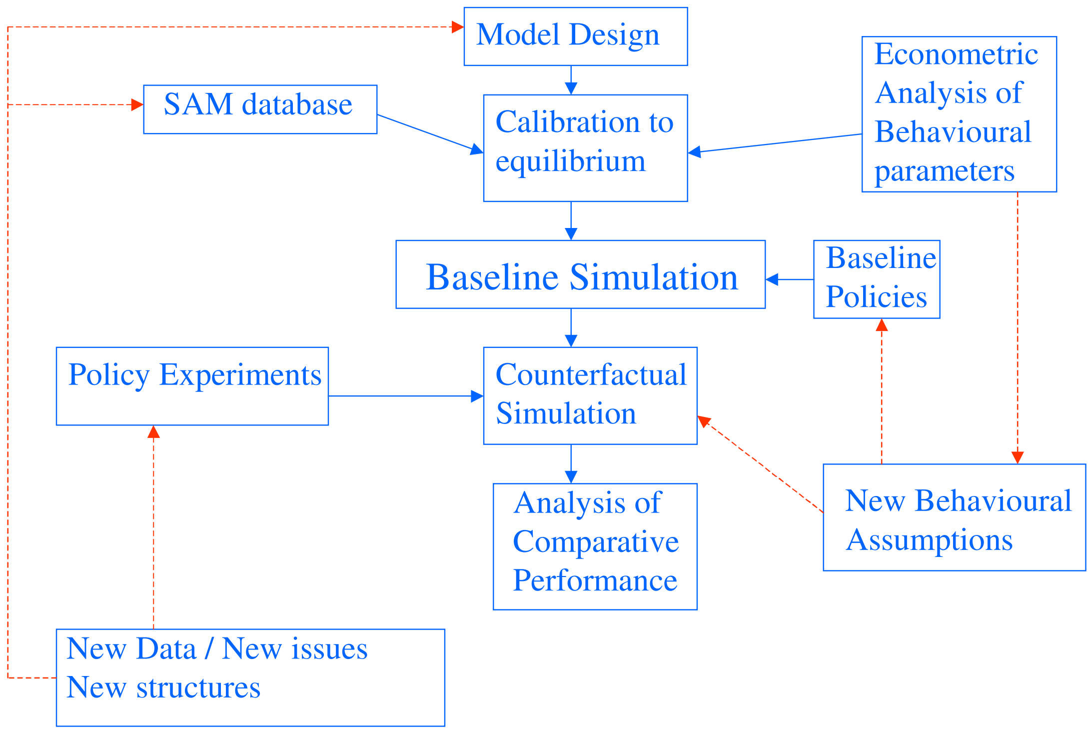
APPENDIX 2: SOCIAL ACCOUNTING MATRIX (SAM) FOR FISHERIES

(Houshak *et al*., 1997)

Social Accounting Matrix with Disaggregated Fishery Sectors

	HARVESTING SECTORS	PROCESSING SECTORS	NONFISHERY SECTORS	HARVESTING COMMOD	PROCESSING COMMOD	NONFISHERY COMMOD	LABOR	CAPITAL	HOUSEHOLD	GOV'T	SAVINGS-INVESTMENT	REST OF WORLD
Harvesting sectors				Make matrix M1	Make matrix M2	Make matrix M3						
Processing sectors				Make matrix M4	Make Matrix M5	Make matrix M6						
Nonfishery sectors				Make matrix M7	Make matrix M8	Make Matrix M9						
Harvesting commodities	Use matrix U1	Use matrix U2	Use matrix U3						Household Purchase H1	Gov't Purchase G1	Investment IN1	Exports E1
Processing commodities	Use matrix U4	Use matrix U5	Use matrix U6						Household Purchase H2	Gov't Purchase G2	Investment IN2	Exports E2
Nonfishery commodities	Use matrix U7	Use matrix U8	Use matrix U9						Household Purchase H3	Gov't Purchase G3	Investment IN3	Exports E3
Labor	Labor income L1	Labor income L2	Labor income L3									
Capital	Capital income K1	Capital income K2	Capital income K3									
Household							Resident Labor Income	Resident Capital Income		Transfer to Household		
Gov't	Indirect business tax T1	Indirect business tax T2	Indirect business tax T3					Corporate tax & Property tax	Personal Income Tax	Transfer to Gov't		
Savings-investment								Depreciation & Retained	Household Savings	Gov't Savings		
Rest of world				Imports IM1	Imports IM2	Imports IM3	Labor Income Leakage	Capital Income Leakage			- (External Savings)	

APPENDIX 3: CGE MODELLING IN PRACTICE



APPENDIX 4: SETS, PARAMETERS and VARIABLES (Salerno-CGE Model)

SETS

$a \in A$ activities
$c \in C$ commodities
$c \in CM$ (C) imported commodities
$c \in CNM$ (C) nonimported commodities
$c \in CE$ (C) exported commodities
$c \in CNE$ (C) nonexported commodities
$f \in F$ factors
$h \in H$ (I) households
$i \in I$ institutions (households, government, and rest of world)

PARAMETERS

ad_a production function efficiency parameter
aq_c shift parameter for composite supply (Armington) function
at_c shift parameter for output transformation (CET) function
ica_{ca} quantity of c as intermediate input per unit of activity a
mps_h share of disposable household income to savings
pwe_c export price (foreign currency)
pwm_c import price (foreign currency)
qg_c government commodity demand
$qinv_c$ base-year investment demand
$shry_{hf}$ share of the income from factor f in household h
te_c export tax rate
tm_c import tariff rate
tq_c sales tax rate
$tr_{ii'}$ transfer from institution i' to institution i
ty_h rate of household income tax
α_{fa} value-added share for factor f in activity a
β_{ch} share of commodity c in the consumption of household h
δ_{cq} share parameter for composite supply (Armington) function
δ_{ct} share parameter for output transformation (CET) function
θ_{ac} yield of commodity c per unit of activity a
ρ_{cq} exponent ($-1 < \rho_{cq} < \infty$) for composite supply (Armington) function
ρ_{ct} exponent ($1 < \rho_{ct} < \infty$) for output transformation (CET) function
σ_{cq} elasticity of substitution for composite supply (Armington) function
σ_{ct} elasticity of transformation for output transformation (CET) function

VARIABLES

EG government expenditure
EXR foreign exchange rate (domestic currency per unit of foreign currency)
$FSAV$ foreign savings
$IADJ$ investment adjustment factor
PA_a activity price
PD_c domestic price of domestic output
PE_c export price (domestic currency)

PM import price (domestic currency)
PQ_c composite commodity price
PVA_c value-added price
PX_c producer price
QA_a activity level
QD_c quantity of domestic output sold domestically
QE_c quantity of exports
QF_{fa} quantity demanded of factor f by activity a
QFS_f supply of factor f
QH_{ch} quantity of consumption of commodity c by household h
$QINT_c$ quantity of intermediate use of commodity c by activity a
$QINV_c$ quantity of investment demand
QM_c quantity of imports
QQ_c quantity supplied to domestic commodity demanders (composite supply)
QX_c quantity of domestic output
$WALRAS$ dummy variable (zero at equilibrium)
WF_f average wage (rental rate) of factor f
$WFDIST_{fa}$ wage distortion factor for factor f in activity a
YF_{hf} transfer of income to household h from factor f
YG government revenue
YH_h household income

APPENDIX 5: Explanation for the Equilibrium Condition

The biological production function is given by:

$$B_{t+1} = B_t + g(B_t) - Y_t \left(1 + \gamma \left(\frac{Y_t}{B_t} \right)^{\beta - 1} \right) \quad (1)$$

with $\gamma = \frac{1-a}{a} \frac{B^{curr}}{Y_{in}^{curr}}$ (2)

We consider two growth models for Salerno:

Fox model $$g(B) = rB \ln\left(\frac{K}{B}\right) \quad (3)$$

Pella-Tomlinson model $$g(B) = rB\left(1 - \left(\frac{B}{K}\right)^{m-1}\right) \quad (4)$$

where B is the biomass of the stock, t is the time step in the model, g is the growth function of the stock, Y is the yield estimated from CGE model, γ is a constant and β is reactivity parameter.

- **Example: Equilibrium Condition**

Consider the case when $a = 1 \Rightarrow \gamma = 0$. Then from equation (1) and (3) we get

$B_{t+1} = B_t + g(B_t) - Y_t$ and

$g(B_t) = rB_t \ln\left(\frac{K}{B_t}\right)$ (Both in general form)

> <u>*Solution:*</u>

$B_1 = B_0 + g(B_0) - Y_0$

<u>For *t = 0*,</u> $g(B_0) = rB_0 \ln\left(\frac{K}{B_0}\right)$ where $B_0 = K/10, Y_0$: initial yield from CGE model

$B_2 = B_1 + g(B_1) - Y_1$

<u>For *t = 1*</u>, $g(B_1) = rB_1 \ln\left(\frac{K}{B_1}\right)$ where Y_1 : is based on B_1.

….

….

….

$B_{t-1} = B_{t-2} + g(B_{t-2}) - Y_{t-2}$

<u>For *t = t-2*</u>, $g(B_{t-2}) = rB_{t-2} \ln\left(\frac{K}{B_{t-2}}\right)$ where Y_{t-2} is based on B_{t-2}.

For $t = t\text{-}1$, $\begin{aligned} B_t &= B_{t-1} + g(B_{t-1}) - Y_{t-1} \\ g(B_{t-1}) &= rB_{t-1}\ln\left(\frac{K}{B_{t-1}}\right) \end{aligned}$ where Y_{t-1} is based on B_{t-1}.

Final step, $\begin{aligned} B_{t+1} &= B_t + g(B_t) - Y_t \\ g(B_t) &= rB_t\ln\left(\frac{K}{B_t}\right) \end{aligned}$ where Y_t is based on B_t.

- **Equilibrium condition**: $B_t = B_{t+1}, \left(\Rightarrow g(B_t) = Y_t\right)$

$$\Rightarrow B_{t-1} + g(B_{t-1}) - Y_{t-1} = B_t + g(B_t) - Y_t \Rightarrow B_{t-1} - B_t = g(B_t) - g(B_{t-1}) - (Y_t - Y_{t-1}) \Rightarrow$$
$$\Rightarrow B_{t-1} + g(B_{t-1}) - Y_{t-1} - B_t = g(B_t) - Y_t$$

Then, the equilibrium condition (state) holds when:

$$(B_{t-1} - B_t) + g(B_{t-1}) - Y_{t-1} = 0.$$

Or

$B_t = B_{t-1} + g(B_{t-1}) - Y_{t-1}$ (That is true, when $t = t\text{-}1$)

Notes:

1. We start with an initial value for biomass B_o ($=K/10$). At each iteration $t+1$, B_{t+1} is estimated from B_t, $g(B_t)$ and Y_t. Each time B_t is given by previous iteration, $g(B_t)$ by biological function and Y_t by economic model.

2. Each time, biomass B is a new value, which then gives a new $g(B)$ and Y. So, at each step i, Y_i is based on B_i and used to estimate B_{i+1} (i.e. the equilibrium biomass corresponding to Y_i).

3. Finally, the model should be converged, and equilibrium condition holds under $g(B_t)=Y_t$, where B and Y are in steady state.

➢ SOME EXAMPLES: DYNAMIC LINK

FOX	an-c		European Ancovy	beta=0									
	B(t)												beta=0
t	B	r	K	ln(K/B)	Y	g(B)	alpha	Ycurr	Yin,curr	gama	Bcurr		B(t+1)
0	7579.4	0.84	75794	2.302585	637	14659.86	0.03	6414	213800	0.32167	2127		19164.2
1	19164.2	0.84	75794	1.374975	637	22134.25	0.03	6414	213800	0.32167	2127		40661.45
2	40661.45	0.84	75794	0.622739	637	21270.03	0.03	6414	213800	0.32167	2127		61294.47
3	61294.47	0.84	75794	0.212329	637	10932.28	0.03	6414	213800	0.32167	2127		71589.75
4	71589.75	0.84	75794	0.057067	637	3431.756	0.03	6414	213800	0.32167	2127		74384.51
5	74384.51	0.84	75794	0.018771	637	1172.893	0.03	6414	213800	0.32167	2127		74920.4
6	74920.4	0.84	75794	0.011593	637	729.5752	0.03	6414	213800	0.32167	2127		75012.98
7	75012.98	0.84	75794	0.010358	637	652.6655	0.03	6414	213800	0.32167	2127		75028.64
8	75028.64	0.84	75794	0.010149	637	639.6414	0.03	6414	213800	0.32167	2127		75031.29
9	75031.29	0.84	75794	0.010114	637	637.4451	0.03	6414	213800	0.32167	2127		75031.73
10	75031.73	0.84	75794	0.010108	637	637.075	0.03	6414	213800	0.32167	2127		75031.81
11	75031.81	0.84	75794	0.010107	637	637.0126	0.03	6414	213800	0.32167	2127		75031.82
12	75031.82	0.84	75794	0.010107	637	637.0021	0.03	6414	213800	0.32167	2127		75031.82
13	75031.82	0.84	75794	0.010107	637	637.0004	0.03	6414	213800	0.32167	2127		75031.82
14	75031.82	0.84	75794	0.010107	637	637.0001	0.03	6414	213800	0.32167	2127		75031.82
15	75031.82	0.84	75794	0.010107	637	637	0.03	6414	213800	0.32167	2127		75031.82
16	75031.82	0.84	75794	0.010107	637	637	0.03	6414	213800	0.32167	2127		75031.82

FOX	an-c		European Ancovy	beta=1								
	B(t)											
t	B	r	K	ln(K/B)	Y	g(B)	alpha	Ycurr	Yin,curr	gama	Bcurr	B(t+1)
0	7579.4	0.84	75794	2.302585	637	14659.86	0.03	6414	213800	0.32167	2127	21397.36
1	21397.36	0.84	75794	1.264752	637	22732.37	0.03	6414	213800	0.32167	2127	43287.82
2	21397.36	0.84	75794	1.264752	637	22732.37	0.03	6414	213800	0.32167	2127	43287.82
3	43287.82	0.84	75794	0.560148	637	20367.97	0.03	6414	213800	0.32167	2127	62813.88
4	43287.82	0.84	75794	0.560148	637	20367.97	0.03	6414	213800	0.32167	2127	62813.88
5	62813.88	0.84	75794	0.187843	637	9911.286	0.03	6414	213800	0.32167	2127	71883.26
6	62813.88	0.84	75794	0.187843	637	9911.286	0.03	6414	213800	0.32167	2127	71883.26
7	71883.26	0.84	75794	0.052976	637	3198.773	0.03	6414	213800	0.32167	2127	74240.13
8	71883.26	0.84	75794	0.052976	637	3198.773	0.03	6414	213800	0.32167	2127	74240.13
9	74240.13	0.84	75794	0.020714	637	1291.776	0.03	6414	213800	0.32167	2127	74690.01
10	74240.13	0.84	75794	0.020714	637	1291.776	0.03	6414	213800	0.32167	2127	74690.01
11	74690.01	0.84	75794	0.014673	637	920.5683	0.03	6414	213800	0.32167	2127	74768.67
12	74690.01	0.84	75794	0.014673	637	920.5683	0.03	6414	213800	0.32167	2127	74768.67
13	74768.67	0.84	75794	0.01362	637	855.4248	0.03	6414	213800	0.32167	2127	74782.19
14	74768.67	0.84	75794	0.01362	637	855.4248	0.03	6414	213800	0.32167	2127	74782.19
15	74782.19	0.84	75794	0.013439	637	844.2207	0.03	6414	213800	0.32167	2127	74784.51
16	74782.19	0.84	75794	0.013439	637	844.2207	0.03	6414	213800	0.32167	2127	74784.51
17	74784.51	0.84	75794	0.013408	637	842.3005	0.03	6414	213800	0.32167	2127	74784.91
18	74784.51	0.84	75794	0.013408	637	842.3005	0.03	6414	213800	0.32167	2127	74784.91
19	74784.91	0.84	75794	0.013403	637	841.9716	0.03	6414	213800	0.32167	2127	74784.97
20	74784.91	0.84	75794	0.013403	637	841.9716	0.03	6414	213800	0.32167	2127	74784.97
21	74784.97	0.84	75794	0.013402	637	841.9153	0.03	6414	213800	0.32167	2127	74784.99
22	74784.97	0.84	75794	0.013402	637	841.9153	0.03	6414	213800	0.32167	2127	74784.99
23	74784.99	0.84	75794	0.013402	637	841.9056	0.03	6414	213800	0.32167	2127	74784.99
24	74784.99	0.84	75794	0.013402	637	841.9056	0.03	6414	213800	0.32167	2127	74784.99

FOX nl-c Nephrops norvegicus (Norway lobster) alpha=1

t	B(t) B	r	K	ln(K/B)	Y	g(B)	B(t+1)	
0	1516.3	0.18	15163	2.302585	250	628.4538	1894.754	B1
1	1894.754	0.18	15163	2.079769	250	709.3171	2354.071	B2
2	2354.071	0.18	15163	1.862712	250	789.2922	2893.363	B3
3	2893.363	0.18	15163	1.656439	250	862.6822	3506.045	B4
4	3506.045	0.18	15163	1.46437	250	924.1463	4180.191	B5
5	4180.191	0.18	15163	1.288501	250	969.5127	4899.704	B6
6	4899.704	0.18	15163	1.129683	250	996.3206	5646.025	B7
7	5646.025	0.18	15163	0.987907	250	1003.994	6400.019	B8
8	6400.019	0.18	15163	0.862557	250	993.669	7143.688	B9
9	7143.688	0.18	15163	0.752629	250	967.7785	7861.466	B10
10	7861.466	0.18	15163	0.656885	250	929.5344	8541.001	B11
11	8541.001	0.18	15163	0.57398	250	882.4255	9173.426	B12
12	9173.426	0.18	15163	0.502547	250	829.8147	9753.241	B13
13	9753.241	0.18	15163	0.441259	250	774.6663	10277.91	B14
14	10277.91	0.18	15163	0.388862	250	719.403	10747.31	B15
15	10747.31	0.18	15163	0.344203	250	665.8656	11163.18	B16
16	11163.18	0.18	15163	0.306238	250	615.3455	11528.52	B17
17	11528.52	0.18	15163	0.274034	250	568.6576	11847.18	B18
18	11847.18	0.18	15163	0.246768	250	526.2318	12123.41	B19
19	12123.41	0.18	15163	0.22372	250	488.2047	12361.62	B20
20	12361.62	0.18	15163	0.204262	250	454.5017	12566.12	B21
21	12566.12	0.18	15163	0.187854	250	424.9076	12741.02	B22
22	12741.02	0.18	15163	0.174031	250	399.1204	12890.15	B23
23	12890.15	0.18	15163	0.162395	250	376.7935	13016.94	B24
24	13016.94	0.18	15163	0.152607	250	357.5651	13124.5	B25
25	13124.5	0.18	15163	0.144377	250	341.0784	13215.58	B26
26	13215.58	0.18	15163	0.137462	250	326.9944	13292.58	B27
27	13292.58	0.18	15163	0.131653	250	315.0002	13357.58	B28
28	13357.58	0.18	15163	0.126774	250	304.812	13412.39	B29
29	13412.39	0.18	15163	0.122679	250	296.1764	13458.57	B30
30	13458.57	0.18	15163	0.119243	250	288.87	13497.44	B31
31	13497.44	0.18	15163	0.116359	250	282.6976	13530.13	B32
32	13530.13	0.18	15163	0.113939	250	277.4898	13557.62	B33
33	13557.62	0.18	15163	0.111909	250	273.1004	13580.72	B34
34	13580.72	0.18	15163	0.110207	250	269.4041	13600.13	B35
35	13600.13	0.18	15163	0.108779	250	266.2938	13616.42	B36
36	13616.42	0.18	15163	0.107582	250	263.6782	13630.1	B37
37	13630.1	0.18	15163	0.106578	250	261.4797	13641.58	B38
38	13641.58	0.18	15163	0.105736	250	259.6327	13651.21	B39
39	13651.21	0.18	15163	0.10503	250	258.0816	13659.29	B40
40	13659.29	0.18	15163	0.104438	250	256.7792	13666.07	B41
41	13666.07	0.18	15163	0.103942	250	255.6861	13671.76	B42
42	13671.76	0.18	15163	0.103526	250	254.7688	13676.53	B43
43	13676.53	0.18	15163	0.103177	250	253.9991	13680.53	B44
44	13680.53	0.18	15163	0.102885	250	253.3534	13683.88	B45
45	13683.88	0.18	15163	0.10264	250	252.8119	13686.69	B46
46	13686.69	0.18	15163	0.102434	250	252.3576	13689.05	B47
47	13689.05	0.18	15163	0.102262	250	251.9767	13691.03	B48
48	13691.03	0.18	15163	0.102118	250	251.6572	13692.68	B49
49	13692.68	0.18	15163	0.101997	250	251.3894	13694.07	B50
50	13694.07	0.18	15163	0.101895	250	251.1648	13695.24	B51
51	13695.24	0.18	15163	0.10181	250	250.9765	13696.21	B52
52	13696.21	0.18	15163	0.101739	250	250.8186	13697.03	B53
53	13697.03	0.18	15163	0.101679	250	250.6862	13697.72	B54
54	13697.72	0.18	15163	0.101629	250	250.5753	13698.29	B55
55	13698.29	0.18	15163	0.101587	250	250.4822	13698.78	B56
56	13698.78	0.18	15163	0.101552	250	250.4043	13699.18	B57
57	13699.18	0.18	15163	0.101522	250	250.3389	13699.52	B58
58	13699.52	0.18	15163	0.101498	250	250.2841	13699.8	B59
59	13699.8	0.18	15163	0.101477	250	250.2381	13700.04	B60
60	13700.04	0.18	15163	0.101459	250	250.1996	13700.24	B61
61	13700.24	0.18	15163	0.101445	250	250.1673	13700.41	B62
62	13700.41	0.18	15163	0.101433	250	250.1403	13700.55	B63
63	13700.55	0.18	15163	0.101422	250	250.1176	13700.67	B64
64	13700.67	0.18	15163	0.101414	250	250.0986	13700.76	B65
65	13700.76	0.18	15163	0.101407	250	250.0826	13700.85	B66
66	13700.85	0.18	15163	0.101401	250	250.0693	13700.92	B67
67	13700.92	0.18	15163	0.101396	250	250.0581	13700.97	B68
68	13700.97	0.18	15163	0.101391	250	250.0487	13701.02	B69
69	13701.02	0.18	15163	0.101388	250	250.0408	13701.06	B70
70	13701.06	0.18	15163	0.101385	250	250.0342	13701.1	B71
71	13701.1	0.18	15163	0.101382	250	250.0287	13701.13	B72

72	13701.13	0.18	15163	0.10138	250	250.024	13701.15	B73
73	13701.15	0.18	15163	0.101378	250	250.0201	13701.17	B74
74	13701.17	0.18	15163	0.101377	250	250.0169	13701.19	B75
75	13701.19	0.18	15163	0.101376	250	250.0142	13701.2	B76
76	13701.2	0.18	15163	0.101375	250	250.0119	13701.21	B77
77	13701.21	0.18	15163	0.101374	250	250.0099	13701.22	B78
78	13701.22	0.18	15163	0.101373	250	250.0083	13701.23	B79
79	13701.23	0.18	15163	0.101372	250	250.007	13701.24	B80
80	13701.24	0.18	15163	0.101372	250	250.0059	13701.25	B81
81	13701.25	0.18	15163	0.101372	250	250.0049	13701.25	B82
82	13701.25	0.18	15163	0.101371	250	250.0041	13701.25	B83
83	13701.25	0.18	15163	0.101371	250	250.0034	13701.26	B84
84	13701.26	0.18	15163	0.101371	250	250.0029	13701.26	B85
85	13701.26	0.18	15163	0.10137	250	250.0024	13701.26	B86
86	13701.26	0.18	15163	0.10137	250	250.002	13701.27	B87
87	13701.27	0.18	15163	0.10137	250	250.0017	13701.27	B88
88	13701.27	0.18	15163	0.10137	250	250.0014	13701.27	B89
89	13701.27	0.18	15163	0.10137	250	250.0012	13701.27	B90
90	13701.27	0.18	15163	0.10137	250	250.001	13701.27	B91
91	13701.27	0.18	15163	0.10137	250	250.0008	13701.27	B92
92	13701.27	0.18	15163	0.10137	250	250.0007	13701.27	B93
93	13701.27	0.18	15163	0.10137	250	250.0006	13701.27	B94
94	13701.27	0.18	15163	0.10137	250	250.0005	13701.27	B95
95	13701.27	0.18	15163	0.101369	250	250.0004	13701.27	B96
96	13701.27	0.18	15163	0.101369	250	250.0003	13701.27	B97
97	13701.27	0.18	15163	0.101369	250	250.0003	13701.27	B98
98	13701.27	0.18	15163	0.101369	250	250.0002	13701.27	B99
99	13701.27	0.18	15163	0.101369	250	250.0002	13701.27	B100
100	13701.27	0.18	15163	0.101369	250	250.0002	13701.27	B101
101	13701.27	0.18	15163	0.101369	250	250.0001	13701.27	B102
102	13701.27	0.18	15163	0.101369	250	250.0001	13701.27	B103
103	13701.27	0.18	15163	0.101369	250	250.0001	13701.28	B104
104	13701.28	0.18	15163	0.101369	250	250.0001	13701.28	B105
105	13701.28	0.18	15163	0.101369	250	250.0001	13701.28	B106
106	13701.28	0.18	15163	0.101369	250	250.0001	13701.28	B107
107	13701.28	0.18	15163	0.101369	250	250	13701.28	B108
108	13701.28	0.18	15163	0.101369	250	250	13701.28	B109

FOX	ep-c	European Pilchard		beta=0									
	B(t)											beta=0	
t	B	r	K	ln(K/B)	Y	g(B)	alpha	Ycurr	Yin,curr	gama	Bcurr	B(t+1)	
0	29642.6	0.22	296426	2.302585	68	15016.01	0.02	6575	328750	1.248885	8379	7570.41	B1
1	7570.41	0.22	296426	3.66755	68	6108.269	0.02	6575	328750	1.248885	8379	13610.68	B2
2	13610.68	0.22	296426	3.080943	68	9225.42	0.02	6575	328750	1.248885	8379	22768.1	B3
3	22768.1	0.22	296426	2.566437	68	12855.24	0.02	6575	328750	1.248885	8379	35555.34	B4
4	35555.34	0.22	296426	2.120707	68	16588.54	0.02	6575	328750	1.248885	8379	52075.88	B5
5	52075.88	0.22	296426	1.739096	68	19924.29	0.02	6575	328750	1.248885	8379	71932.17	B6
6	71932.17	0.22	296426	1.416074	68	22409.48	0.02	6575	328750	1.248885	8379	94273.65	B7
7	94273.65	0.22	296426	1.145596	68	23759.89	0.02	6575	328750	1.248885	8379	117965.5	B8
8	117965.5	0.22	296426	0.921405	68	23912.69	0.02	6575	328750	1.248885	8379	141810.2	B9
9	141810.2	0.22	296426	0.737308	68	23002.72	0.02	6575	328750	1.248885	8379	164744.9	B10
10	164744.9	0.22	296426	0.587399	68	21289.63	0.02	6575	328750	1.248885	8379	185966.6	B11
11	185966.6	0.22	296426	0.466231	68	19074.73	0.02	6575	328750	1.248885	8379	204973.3	B12
12	204973.3	0.22	296426	0.368918	68	16636.03	0.02	6575	328750	1.248885	8379	221541.3	B13
13	221541.3	0.22	296426	0.291188	68	14192.26	0.02	6575	328750	1.248885	8379	235665.6	B14
14	235665.6	0.22	296426	0.229384	68	11892.73	0.02	6575	328750	1.248885	8379	247490.3	B15
15	247490.3	0.22	296426	0.180426	68	9823.819	0.02	6575	328750	1.248885	8379	257246.1	B16
16	257246.1	0.22	296426	0.141764	68	8023.027	0.02	6575	328750	1.248885	8379	265201.2	B17
17	265201.2	0.22	296426	0.111309	68	6494.238	0.02	6575	328750	1.248885	8379	271627.4	B18
18	271627.4	0.22	296426	0.087366	68	5220.839	0.02	6575	328750	1.248885	8379	276780.2	B19
19	276780.2	0.22	296426	0.068574	68	4175.57	0.02	6575	328750	1.248885	8379	280887.8	B20
20	280887.8	0.22	296426	0.053842	68	3327.2	0.02	6575	328750	1.248885	8379	284147	B21
21	284147	0.22	296426	0.042306	68	2644.638	0.02	6575	328750	1.248885	8379	286723.7	B22
22	286723.7	0.22	296426	0.033279	68	2099.197	0.02	6575	328750	1.248885	8379	288754.8	B23
23	288754.8	0.22	296426	0.02622	68	1665.625	0.02	6575	328750	1.248885	8379	290352.5	B24
24	290352.5	0.22	296426	0.020702	68	1322.393	0.02	6575	328750	1.248885	8379	291606.9	B25
25	291606.9	0.22	296426	0.016391	68	1051.544	0.02	6575	328750	1.248885	8379	292590.4	B26
26	292590.4	0.22	296426	0.013024	68	838.3467	0.02	6575	328750	1.248885	8379	293360.8	B27
27	293360.8	0.22	296426	0.010395	68	670.8547	0.02	6575	328750	1.248885	8379	293963.6	B28
28	293963.6	0.22	296426	0.008342	68	539.4691	0.02	6575	328750	1.248885	8379	294435.1	B29
29	294435.1	0.22	296426	0.006739	68	436.528	0.02	6575	328750	1.248885	8379	294803.6	B30
30	294803.6	0.22	296426	0.005488	68	355.9475	0.02	6575	328750	1.248885	8379	295091.6	B31
31	295091.6	0.22	296426	0.004512	68	292.9158	0.02	6575	328750	1.248885	8379	295316.5	B32
32	295316.5	0.22	296426	0.00375	68	243.6387	0.02	6575	328750	1.248885	8379	295492.1	B33
33	295492.1	0.22	296426	0.003155	68	205.1316	0.02	6575	328750	1.248885	8379	295629.2	B34
34	295629.2	0.22	296426	0.002691	68	175.0509	0.02	6575	328750	1.248885	8379	295736.3	B35
35	295736.3	0.22	296426	0.002329	68	151.5588	0.02	6575	328750	1.248885	8379	295819.9	B36
36	295819.9	0.22	296426	0.002047	68	133.2161	0.02	6575	328750	1.248885	8379	295885.1	B37
37	295885.1	0.22	296426	0.001827	68	118.8963	0.02	6575	328750	1.248885	8379	295936	B38
38	295936	0.22	296426	0.001655	68	107.7186	0.02	6575	328750	1.248885	8379	295975.7	B39
39	295975.7	0.22	296426	0.00152	68	98.9944	0.02	6575	328750	1.248885	8379	296006.7	B40
40	296006.7	0.22	296426	0.001416	68	92.18564	0.02	6575	328750	1.248885	8379	296030.9	B41
41	296030.9	0.22	296426	0.001334	68	86.87212	0.02	6575	328750	1.248885	8379	296049.7	B42
42	296049.7	0.22	296426	0.00127	68	82.72566	0.02	6575	328750	1.248885	8379	296064.5	B43
43	296064.5	0.22	296426	0.00122	68	79.49005	0.02	6575	328750	1.248885	8379	296076	B44
44	296076	0.22	296426	0.001182	68	76.96527	0.02	6575	328750	1.248885	8379	296084.9	B45
45	296084.9	0.22	296426	0.001151	68	74.99521	0.02	6575	328750	1.248885	8379	296091.9	B46
46	296091.9	0.22	296426	0.001128	68	73.45802	0.02	6575	328750	1.248885	8379	296097.4	B47
47	296097.4	0.22	296426	0.001109	68	72.2586	0.02	6575	328750	1.248885	8379	296101.6	B48
48	296101.6	0.22	296426	0.001095	68	71.32274	0.02	6575	328750	1.248885	8379	296105	B49
49	296105	0.22	296426	0.001084	68	70.59253	0.02	6575	328750	1.248885	8379	296107.5	B50
50	296107.5	0.22	296426	0.001075	68	70.02279	0.02	6575	328750	1.248885	8379	296109.6	B51
51	296109.6	0.22	296426	0.001068	68	69.57825	0.02	6575	328750	1.248885	8379	296111.1	B52
52	296111.1	0.22	296426	0.001063	68	69.23141	0.02	6575	328750	1.248885	8379	296112.4	B53
53	296112.4	0.22	296426	0.001059	68	68.96079	0.02	6575	328750	1.248885	8379	296113.3	B54
54	296113.3	0.22	296426	0.001055	68	68.74964	0.02	6575	328750	1.248885	8379	296114.1	B55
55	296114.1	0.22	296426	0.001053	68	68.58489	0.02	6575	328750	1.248885	8379	296114.7	B56
56	296114.7	0.22	296426	0.001051	68	68.45635	0.02	6575	328750	1.248885	8379	296115.1	B57
57	296115.1	0.22	296426	0.001049	68	68.35606	0.02	6575	328750	1.248885	8379	296115.5	B58
58	296115.5	0.22	296426	0.001048	68	68.27781	0.02	6575	328750	1.248885	8379	296115.8	B59
59	296115.8	0.22	296426	0.001047	68	68.21675	0.02	6575	328750	1.248885	8379	296116	B60
60	296116	0.22	296426	0.001046	68	68.16912	0.02	6575	328750	1.248885	8379	296116.1	B61
61	296116.1	0.22	296426	0.001046	68	68.13195	0.02	6575	328750	1.248885	8379	296116.3	B62
62	296116.3	0.22	296426	0.001045	68	68.10295	0.02	6575	328750	1.248885	8379	296116.4	B63
63	296116.4	0.22	296426	0.001045	68	68.08033	0.02	6575	328750	1.248885	8379	296116.5	B64
64	296116.5	0.22	296426	0.001045	68	68.06267	0.02	6575	328750	1.248885	8379	296116.5	B65
65	296116.5	0.22	296426	0.001045	68	68.0489	0.02	6575	328750	1.248885	8379	296116.6	B66
66	296116.6	0.22	296426	0.001044	68	68.03815	0.02	6575	328750	1.248885	8379	296116.6	B67
67	296116.6	0.22	296426	0.001044	68	68.02977	0.02	6575	328750	1.248885	8379	296116.6	B68
68	296116.6	0.22	296426	0.001044	68	68.02323	0.02	6575	328750	1.248885	8379	296116.7	B69
69	296116.7	0.22	296426	0.001044	68	68.01812	0.02	6575	328750	1.248885	8379	296116.7	B70
70	296116.7	0.22	296426	0.001044	68	68.01414	0.02	6575	328750	1.248885	8379	296116.7	B71
71	296116.7	0.22	296426	0.001044	68	68.01103	0.02	6575	328750	1.248885	8379	296116.7	B72

72	296116.7	0.22	296426	0.001044	68	68.00861	0.02	6575	328750	1.248885	8379	296116.7	B73
73	296116.7	0.22	296426	0.001044	68	68.00672	0.02	6575	328750	1.248885	8379	296116.7	B74
74	296116.7	0.22	296426	0.001044	68	68.00524	0.02	6575	328750	1.248885	8379	296116.7	B75
75	296116.7	0.22	296426	0.001044	68	68.00409	0.02	6575	328750	1.248885	8379	296116.7	B76
76	296116.7	0.22	296426	0.001044	68	68.00319	0.02	6575	328750	1.248885	8379	296116.7	B77
77	296116.7	0.22	296426	0.001044	68	68.00249	0.02	6575	328750	1.248885	8379	296116.7	B78
78	296116.7	0.22	296426	0.001044	68	68.00194	0.02	6575	328750	1.248885	8379	296116.7	B79
79	296116.7	0.22	296426	0.001044	68	68.00152	0.02	6575	328750	1.248885	8379	296116.7	B80
80	296116.7	0.22	296426	0.001044	68	68.00118	0.02	6575	328750	1.248885	8379	296116.7	B81
81	296116.7	0.22	296426	0.001044	68	68.00092	0.02	6575	328750	1.248885	8379	296116.7	B82
82	296116.7	0.22	296426	0.001044	68	68.00072	0.02	6575	328750	1.248885	8379	296116.7	B83
83	296116.7	0.22	296426	0.001044	68	68.00056	0.02	6575	328750	1.248885	8379	296116.7	B84
84	296116.7	0.22	296426	0.001044	68	68.00044	0.02	6575	328750	1.248885	8379	296116.7	B85
85	296116.7	0.22	296426	0.001044	68	68.00034	0.02	6575	328750	1.248885	8379	296116.7	B86
86	296116.7	0.22	296426	0.001044	68	68.00027	0.02	6575	328750	1.248885	8379	296116.7	B87
87	296116.7	0.22	296426	0.001044	68	68.00021	0.02	6575	328750	1.248885	8379	296116.7	B88
88	296116.7	0.22	296426	0.001044	68	68.00016	0.02	6575	328750	1.248885	8379	296116.7	B89
89	296116.7	0.22	296426	0.001044	68	68.00013	0.02	6575	328750	1.248885	8379	296116.7	B90
90	296116.7	0.22	296426	0.001044	68	68.0001	0.02	6575	328750	1.248885	8379	296116.7	B91
91	296116.7	0.22	296426	0.001044	68	68.00008	0.02	6575	328750	1.248885	8379	296116.7	B92
92	296116.7	0.22	296426	0.001044	68	68.00006	0.02	6575	328750	1.248885	8379	296116.7	B93
93	296116.7	0.22	296426	0.001044	68	68.00005	0.02	6575	328750	1.248885	8379	296116.7	B94
94	296116.7	0.22	296426	0.001044	68	68.00004	0.02	6575	328750	1.248885	8379	296116.7	B95
95	296116.7	0.22	296426	0.001044	68	68.00003	0.02	6575	328750	1.248885	8379	296116.7	B96
96	296116.7	0.22	296426	0.001044	68	68.00002	0.02	6575	328750	1.248885	8379	296116.7	B97
97	296116.7	0.22	296426	0.001044	68	68.00002	0.02	6575	328750	1.248885	8379	296116.7	B98
98	296116.7	0.22	296426	0.001044	68	68.00001	0.02	6575	328750	1.248885	8379	296116.7	B99
99	296116.7	0.22	296426	0.001044	68	68.00001	0.02	6575	328750	1.248885	8379	296116.7	B100
100	296116.7	0.22	296426	0.001044	68	68.00001	0.02	6575	328750	1.248885	8379	296116.7	B101
101	296116.7	0.22	296426	0.001044	68	68.00001	0.02	6575	328750	1.248885	8379	296116.7	B102
102	296116.7	0.22	296426	0.001044	68	68.00001	0.02	6575	328750	1.248885	8379	296116.7	B103
103	296116.7	0.22	296426	0.001044	68	68	0.02	6575	328750	1.248885	8379	296116.7	B104
104	296116.7	0.22	296426	0.001044	68	68	0.02	6575	328750	1.248885	8379	296116.7	B105