A preliminary microworld to gain insights in Belgian fishery fleet dynamics.

Hendrik Stouten[a], Kris Van Craeynest[b], Aimé Heene[c], Xavier Gellynck[d], Jochen Depestele[b], Els Vanderperren[b], Bart Verschueren[b], Hans Polet[b]

[a] Institute for Agriculture and Fisheries Research (ILVO)/ Faculty of Economics and Business Administration, Ghent University
Ankerstraat 1, B-8400 Ostend, Belgium
Phone: (0032) 479 20 23 26
Hendrik.Stouten@ilvo.vlaanderen.be

[b] Institute for Agriculture and Fisheries Research (ILVO)
Ankerstraat 1, B-8400 Ostend, Belgium
Phone: (0032) 59 34 22 50

[c] Professor, Department Management and Organization, Faculty of Economics and Business Administration, Ghent University
Tweekerkentstraat 2, B-9000 Ghent, Belgium
Phone: (0032) 475 48 24 26
Aime.Heene@UGent.be

[d] Professor, Department of Agricultural Economics, Faculty of Bio-Science Engineering, Ghent University
Coupure Links 653, B-9000 Ghent, Belgium
Phone: (0032) 9 264 59 23
Xavier.Gellynck@UGent.be

Abstract

The objective of this paper is to develop and evaluate a micro-economical microworld which will allow policy makers to gain more insight in parameters that influence the Belgian fishery fleet structure.

In a later stage, this microworld may contribute to the process of developing a long-term strategy for the Belgian fishery sector, serving as a laboratory for ex-ante evaluation of possible strategies. (Keys, Fulmer, and Stumpf 1996; De Geus 1997) By visualizing decisions and strategies (Morecroft 1999), it generates insights about fleet dynamics in response to a changing environment and policy changes.

Key words: Microworld, fleet dynamics, system dynamics, policy testing.

1. Introduction

Fishing is an important economic activity in coastal areas. In the NE-Atlantic region of the European Union, about 60’000 fishing vessels are active with total landings of about 4.5 million tonnes of fish and shellfish. The direct employment is almost 200’000 fishermen and there is an important indirect employment depending on fisheries. For coastal communities, fishery is also important from a socio-cultural point of view.

With more than 30 fish species under quota regulations and a wide range of vessel types and fishing methods, the NE-Atlantic region is a complex area to manage. In its “Green Paper”, the European Commission (EC) clearly stated that the Common Fisheries Policy (CFP) has failed. Fish stocks are under pressure, fishing effort is too high, several types of fishing gear are not selective enough and harmful to the environment and the mixed character of many fisheries renders the management of stocks difficult. Moreover, the fishery sector which was already lacking economic performance, is now suffering from high fuel prices.

It is in this complex and changing uncertain environment that the Belgian fishing fleet operates. Therefore it is clear that a long-term strategy is needed to safeguard the future of the Belgian fishery sector.

2. Objective

The objective of this paper is to develop and evaluate a micro-economical microworld which will allow policy makers to gain more insight in parameters that influence the Belgian fleet structure.

In a later stage, this microworld may contribute to the process of developing a long-term strategy for the Belgian fishery sector, serving as a laboratory for ex-ante evaluation of possible strategies. (Keys, Fulmer, and Stumpf 1996; De Geus 1997) By visualising decisions and strategies (Morecroft 1999), it generates insights about fleet dynamics in response to a changing environment and policy changes.

3. The Belgian fleet problem

a. A double overspecialisation of the fleet

In the NE-Atlantic region of the European Union, the Belgian sea fishery industry is an interesting case. As in many other countries, it lacks economical stability (company profits are decreasing) due to decreasing production and increasing costs. A double overspecialisation of the fleet, both towards target species (mainly sole and plaice) (Tessens and Velghe 2004, 2005) and towards the fishing method (over 85% of the fleet consists of beam trawlers) (Tessens and Velghe 2004, 2005) makes the Belgian fleet especially vulnerable to fluctuations in fish quota (Bjorndal and Conrad 1987) and costs (i.e. fuel, steel, etc.).

b. The overspecialisation of the fleet in economic terms

Almost the entire Belgian fleet consists out of beam trawlers (102 beam trawlers of a total of 119 vessels). These vessels tow heavy fishing gear over the sea-bed which results in a relatively high fuel consumption. Within the fleet of Belgian beam trawlers, three major important vessel types can be distinguished:

1) Large beam trawler: beam trawler > 662 kW (52 vessels in 2005)
2) Eurocutter: beam trawlers between 200 kW and 221 kW not targeting shrimps (35 vessels in 2005)
3) Shrimp trawler: beam trawlers targeting shrimps (15 vessels in 2005)

Table 1 – Economic data for the year 2005 in euro (Averages for different beam trawlers in the Belgian fishery fleet)

	Large beam trawler	Eurocutter	Shrimp trawler
Revenues	***1'243'518***	***524'178***	***194'280***
Labour costs	347'657	154'277	47'426
Unload- and Sales Costs	95'352	35'502	4'479
Insurances	49'225	19'798	7'252
Maintenance costs	83'955	36'886	18'508
Costs fishing gear	74'658	33'100	7'962
Gas costs	520	422	891
Fuel costs	462'803	133'824	51'735
Costs for board equipment	1'595	1'171	0
Other costs	44'661	25'846	19'312
Total costs	***1'160'430***	***440'832***	***157'569***
GROSS OPERATING PROFIT	**83'087**	**83'346**	**36'710**
Depreciations	232'067	84'392	12'953
NET OPERATING PROFIT	**-148'980**	**-1'046**	**23'756**

Data source: Belgian Sea Fisheries Service

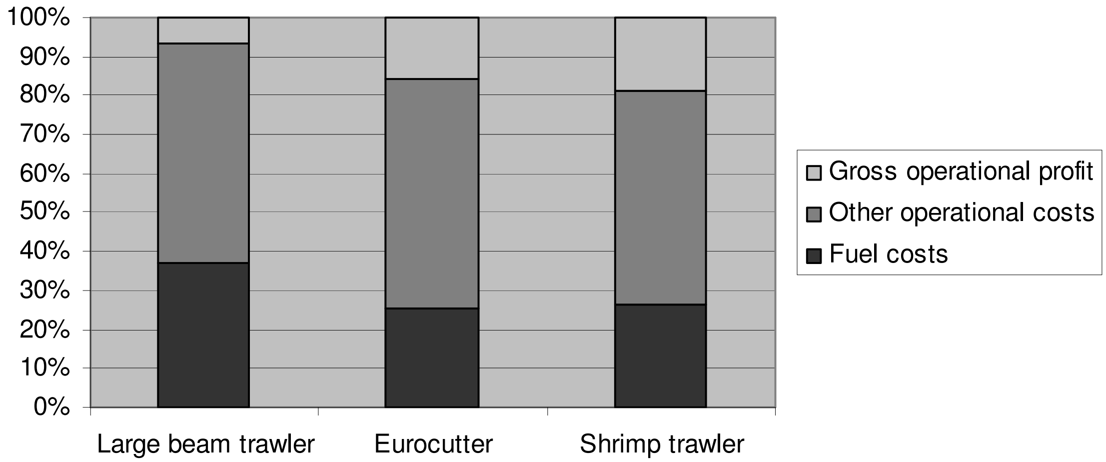

Figure 1 – Fuel and other operational costs as a percentage of revenue (Averages for different beam trawlers in the Belgian fishery fleet)

Translated to the entire Belgian fleet, this means that for eurocutters and shrimp trawlers 25% of revenues go to fuel and for large beam trawlers nearly 40%. Roughly estimated this means that approximately 30% of the value of all Belgian fish quota (catch) is spent on fuel. Today, many trips at sea result in a financial loss for the owners of beam trawlers and it is clear that the beam trawler fleet is on the edge of not being profitable.

On the other hand, there are examples in Belgium of fishing vessels carrying out a very profitable fishery based on passive fishing methods with a fuel bill less than 5% of the revenues. It is clear that profitable alternatives exist but a conversion of the fleet is not straightforward. Problems of investment costs, conflicts between fishing methods, availability of sufficient quota and suitable fishing grounds, lack of fishermen's knowledge of alternative fishing methods can hinder a conversion.

It is therefore necessary that potential alternatives are studied thoroughly so that realistic options (in terms of vessel type and fishing method) can be presented to the industry and a restructuring of the fleet can start. A well organised conversion will be necessary for the fleet to survive and achieve a sustainable fishery in the broadest sense, i.e. a fleet that is profitable, not harmful to the environment and fish stocks, taking the social life of the fisherman into account, applying modern fishing techniques with attention to safety, etc.

4. How to gain insights in the Belgian fleet structure

Since fleet dynamics was defined in the 1980's (Gillis 2003) modelling has been an important method for gaining insights in the behaviour of fleet structures. Modelling fleet structures can be performed from two perspectives (macro- and micro-economical) and by using a number of different modelling techniques (probabilistic modelling, optimisation modelling, system dynamics modelling, etc.).

The macro-economical approach investigates how a fleet or subfleet as a whole interacts with its biological, legal and political environment. In a micro-economical approach it is often the behaviour of a single vessel, fisherman or company (in the bigger entity of the fleet and environment) which is the main research object.

Through a brief literature review, this paper will explain and justify its choice for the micro-economical approach applied in the preliminary microworld.

a. Studies from a macro-economical approach

One type of macro-economical study that often occurs in fleet dynamics evaluates and/or predicts the impact of policies and/or biological changes on fleet structures (Shalliker 1987; Moxnes 2003; Moxnes 1999; Le Gallic 2000). Strongly related to the latter, are studies that investigate how harvesting has an impact on fish populations (Finnoff and Tschirhart 2003; Dudley 2003; Ruttan et al. 2004).

Another large category of macro-economical studies are related to the field of 'game theory'. Laukkanen (2003) for example developed a harvesting game where two fleets harvest in a stochastic interception fishery. He examined cooperation versus non-cooperation. A similar study was performed by Ruttan et al. (2004), where a method was presented to evaluate the economic losses and biological impacts of a lack of co-ordination of effort on the part of small versus large-scale fisheries.

b. Studies from a micro-economical approach

Since fleet dynamics was defined in the 1980's there has been increasing interest in the role played by vessel behaviour in the exploitation of aquatic resources (Gillis 2003). In 1985, Hilborn (1985) has identified the four main research areas of fleet dynamics: investment and disinvestment decisions, effort allocation, harvesting efficiency and discarding fish and fish mortality.

In the literature of the micro-economical approach on fleet dynamics, studies (models) on investment and disinvestment decisions (Bosetti and Tomberlin 2004; Clark, Clarke, and Munro 1979; Boyce John 1995), effort allocation and harvesting efficiency (Anderson 1999; Hutton et al. 2004; Andersen and Christensen 2005; Salas, Sumaila, and Pitcher 2004; Rijnsdorp, van Mourik Broekman, and Visser 2000; Salas and Gaertner 2004; Béné and Tewfik 2001; Laloe et al. 1998; Gillis 2003; Helu, Anderson, and Sampson 1999) are indeed often performed.

Other interesting topics on fleet dynamics study how fishing captains, consumers, and input suppliers each attempt to influence the regulator's choice of instruments (Boyce 2004) or study the learning behaviour (learning models) of fishermen (Xiao 2004).

5. Towards the microworld

Before developing a microworld two steps need to be taken. First of all, clear goals need to be set for the microworld. Secondly, a suitable modelling technique and modelling approach (micro or macro approach) need to be chosen.

a. *What do we desire from the microworld?*

In the short run, the microworld needs to allow policy makers to gain more insights in parameters which can or will influence the Belgian fleet structure.

In the long run, it must serve the strategy building process for the Belgian fishery sector. It will serve as a laboratory for ex-ante evaluation of possible strategies. (Keys, Fulmer, and Stumpf 1996; De Geus 1997) By visualizing decisions and strategies (Morecroft 1999), it will generate insights about fleet dynamics.

b. Modelling approach and technique

The approach of the microworld is a micro-economical one, following Helu et al. (1999) in their belief that focusing on the behaviour of individual boat owners will lead to a (better) understanding of fleet dynamics. In this way, the dynamics of individual boat owners determine the general dynamics of the fleet. Further more, this enables evaluating the performance of individual companies and vessels that follows from the impact of policies on their individual management decisions.

The modelling technique used is system dynamics, following the work of Moxnes (2003; Moxnes 1998; Moxnes 1999) and Dudley (2003; Dudley 2003, 2003). The advantages of using system dynamics as a modelling technique in general are:

- It is very user-friendly, although it is based on mathematical equations.
- It offers a graphical interface to make model building and communication a lot easier.
- It allows communicating highly complex, non-linear models in an understandable way.
- It unveils the dynamic behaviour of the system by examining the loops and delays how are responsible for complex and non-linear behaviour.
- It is a learning tool.

Translated to fleet dynamics from a micro-economical point of view, this means that system dynamics will be able to map the feedback loops and delays packed in the environment in which fishermen and there vessels operate. System dynamics will be able to visualise these two important elements (feedback loops and delays) and bring them to the attention of policymakers.

c. *The scope of the microworld*

Defining the scope of the microworld often hides a huge trade-off problem between simplification and representation of the subject under research (real world). Brehmer (2005) refers to this problem as the 'cat problem': "The best simulation of a cat is another cat. The problem, of course, is that the second '(simulated-)cat' is just as complex and in-transparent as the first '(real world-)cat'. The lesson for designers of microworlds is clear: some simplification is needed. This, in turn, requires some explicit frame of reference to guide this simplification and to inform about what can be safely left out of the simulations and what must be part of them." Morecroft (1999) calls this: "The art of good (business) modeling".

Translating this theory into practice means that the Belgian sea fishery can not be modelled as an open system due to its huge complexity. Therefore, boundaries and constraints are needed to construct a well defined framework (Hjorth and Bagheri 2006). Different constraints are needed in terms of 1) variables, 2) arrays, and 3) decision points included in the microworld.

To define the choice in variables, a model building chart (Sterman 2000) is used (table 2).

Table 2 – Model building chart

Endogenous variables	Exogenous variables	Not considered
• Financial data per vessel type (Costs, revenues, savings, etc) • 2 decision algorithms (decision to fish and investment decisions)	• Prices (Fuel, material, Fish, etc.) • Initial Quota • Initial licenses • Policies	• Biological variables (stock dynamics) • Aquaculture

Only three array constraints are included in the preliminary microworld: 1) company type (one company which prefers eurocutter versus one which prefers large beam trawler), 2) vessel type (large beam trawler and eurocutter) and 3) fishing ground (two nearby and one further away). The model does not include different target species, there is only one theoretical target species.

A last constraint concerns the choice in decision points. In the preliminary microworld fishing companies need to take only two decisions: 1) about there fishing activities (where to fish, how to fish), and 2) an investment decision. Currently, these decision points are oversimplified in the preliminary microworld by using thresholds.

6. The preliminary microworld

The current preliminary microworld (see annex 1) aggregates the behaviour of individual companies and their vessels. This aggregation illustrates, from a micro-economical perspective, how the fleet structure can change due to the impact of policies on individual company and vessel behaviour.

The microworld is built around a classic investment-loop. This loop is by nature a reinforcing loop, namely: the more a company earns, the more it can invest, the more it can earn again. It is a loop which needs to be balanced in time. Three obvious components are able to balance this reinforcing loop: 1) costs, 2) legislation (e.g. licenses), and 3) biological components (e.g. fish stocks). Costs and legislation are incorporated in the microworld, but biological components are not. In defining the scope, we decided to leave it out of the microworld.

a. *Describing the current microworld*

The current microworld is written with a time interval (dt) of one day. This means that the microworld recalculates its output matrix each day. The model 'starts' with a decision (decision point) each company has to make: will I send my vessels out to fish? And if yes, to which fishing ground? Currently, this decision depends on 1) remaining quota, 2) fishing days, and 3) good fish prices. If these are all still above zero (a threshold value), the company sends off its vessels to its desired fishing ground. Otherwise, the vessels stay in their homeport.

When companies sail off with their vessel, variable costs and revenues (catches) start running resulting in earnings or losses. These earnings are collected in a savings account of the company. The amount of money on its account will affect its possibility to invest or disinvest (vessel demolition). This question represents a second important decision point in the microworld. When an investment decision occurs, depends on threshold values for savings and number of vessels available in the company.

Not only do the trips influence the savings of the company, they also influence the amount of fishing days and quota left per fishing ground. Both will decline during the simulation of a year, but after each year a fresh constant value for both is shot into the microworld by means of a pulse function.

There is also an important balancing loop on the number of vessels a company can have. This is balanced by the availability of licenses (fixed number).

The combination of the above feedback loops, decision points and arrays will contribute to gaining insights in the dynamics of micro-economical vessel and company behaviour in fleet dynamics

b. *A simplified scheme*

The text above can be converted into a simplified (e.g. no arrays) system dynamics microworld (full preliminary microworld in equations: see annex 1).

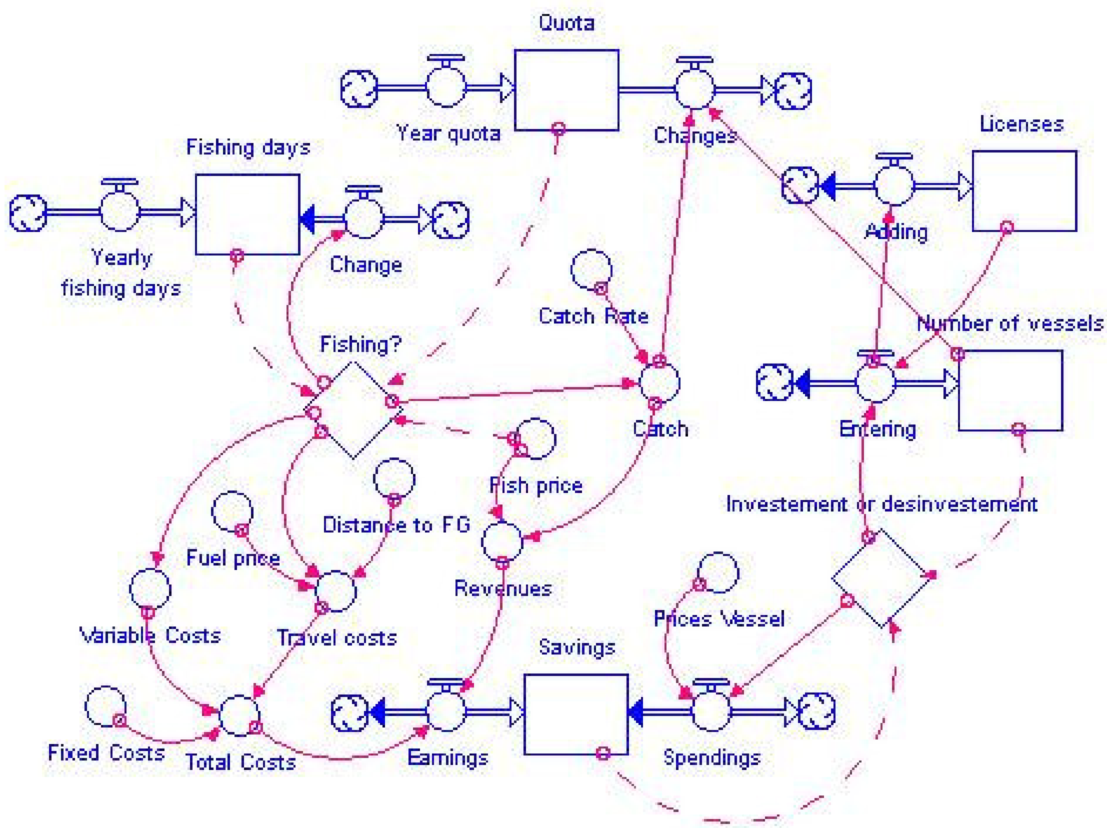

Figure 2 – A simplified system dynamics microworld of individual vessel and company behaviour (whereby: □ = stock, ○ = converter and ◊ = decision point)

c. The output format of the microworld

The output of this preliminary microworld can be summarized in a (dynamical) matrix, whereby each cell can be represented by a 'behaviour over time'-graph.

Table 3 – Output of the preliminary microworld

	Cost structure	Revenue	Earning	Savings	Number of vessels	Licenses	Fishing days
Company 1	∑	∑	∑	∑	∑	∑	∑
• Vessel type 1							
• Vessel type 2							
Company 2	∑	∑	∑	∑	∑	∑	∑
• Vessel							

type 1							
• Vessel type 2							
Total fleet	∑	∑	∑	∑	∑	∑	∑

This output format allows visualising the impact of different policies on the economical performance of the individual company level and entire fleet. In this way, it allows policy makers to gain more insights in parameters which can or will influence the Belgian fleet structure.

7. Policy testing through the microworld

a. The expansion of the fisheries management paradigm

The fisheries management paradigm has changed from a purely biological (1930's), over a more bioeconomical (1950's), to finally a political bioregunomics approach (late 1980's).

The biological approach (Russell 1931; Graham 1935) of fisheries management was primarily done by fisheries biologists. The centre of their attention was the stock of fish and how it changed over time. Policies following from the biological approach were: total quota, gear restriction, closed seasons, closed areas, etc. (Anderson 1987)

The bioeconomic approach (Gordon 1953, 1954; Scott 1955; Crutchfield 1956, 1959) deals with the interaction of the stock and the industry. Policies following from this approach were: limited entry programs, transferable individual quotas, taxes, etc.

The political bioregunomics approach (Anderson 1987; Walters 1980) looks at the three-way interaction among fish stocks, industry, and government entities. The underlying assumption is that it is also important to study why agency officials implement the types of regulations they do.

b. Which policies will be tested and how do they interfere with the microworld

The main goal of developing the microworld is to investigate the impact of policies related to the biological and bioeconomic approach since both still form the basis of the current fishery policy.

The policies which will be tested are mentioned in table 4, where 'change in variable' means how the policy will be implemented in the microworld, 'impact on preliminary microworld' clarifies how it will impact the fleet dynamics and 'further desired behaviour' reflects on future improvements which will be made to the microworld in order to enhance its performance (i.e. to give a more realistic picture of the impact of different policies).

Table 4 – Policies which will be tested by the microworld (VT = Vessel type, FG = Fishing ground and TS = Target Species)

Policy		**Change in variable**	**Impact on preliminary microworld**	**Further desired behaviour**
Subsidies	Investment subsidies	Price for a vessel per VT (Buying)	An investment subsidy will only reduce the outflow of money from the stock 'savings' for each investment a company makes.	An investment subsidy should also have an impact on the investment decision point (e.g. investments occur more easy, …)
	Demolition subsidies	Price for a vessel per VT (Selling)	An demolition subsidy will only enlarge the outflow of money from the stock 'savings' for each disinvestment a company makes.	A demolition subsidy should also have an impact on the disinvestment decision (e.g. demolition becomes more attractive).
	Subsidies on fuel costs	Fuel price	A subsidy on the fuel costs means that fuel costs will be reduced while fishing.	/
Price regulations	Maximum fish price	Fish price	Maximum fish prices only reduce the revenues in the preliminary microworld.	Later on, the microworld should contain more then one TS. A maximum fish price for certain TS should affect the 'fishing decision point'. Some fishermen will start to target less interesting TS because they will believe there is more profit to it.
	Minimum price for target species	Fish price	Minimum fish prices only ensure a certain amount of revenues in the preliminary microworld.	With more then one TS, a minimum fish price for certain TS should affect the 'fishing decision point'. Some fishermen will start to target less interesting TS because there is a certain income guaranteed.
Quota regulations	More/less quota per FG	Quota per FG	There is more/less quota on a FG to be caught. This can result in being able to fish more during the year.	It would be nice if changes in quota are not only made by FG but also by TS.
	Level of diversification of the quota over different FG's	Quota per FG	The level of diversification of the quota over the different FG's will influence the travel costs.	/
License regulations	More/less licenses	Licenses	More/less licenses will influence the maximum size of the fleet.	In the final microworld, it should allow to split a license of a large beam trawler into two licenses for eurocutter.
Closing fishing grounds	A FG becomes closed	Quota per FG	There is less quota to be caught, the vessels will not visit the closed FG any more. (Closing a FG can only be done in the beginning of the simulation and rests till the end. Predefining changes during the simulation are not possible yet)	Make predefinition of changes in closed FG possible.

8. Data used in the preliminary microworld

a. Data Analysis

The preliminary microworld uses a huge amount of different data. By analysing the microworld, four main topics were found where data is needed (Figure 3):

- Fishing Grounds (FG)
- Vessel Types (VT)
- Target Species (TS)
- Company (C)

Table 5 - Data analysis chart (The data which is used in the preliminary is given for each array)

Fishing Ground (FG)	**Target Species (TS)**	**Vessel Type (VT)**
• Distance from harbor	• Price	• Fixed Costs • Variable Costs (exclusive travel costs) • Travel Costs • Price (Buying and selling)

FG * TS	**VT * FG**
• Initial Quota	• Productivity rate

b. Data gathering

This preliminary microworld uses data from two institutes. Firstly, there is a useful database (under construction) called 'Belsamp' in the Institute for Agriculture and Fisheries Research (ILVO). The major problem of this database is that it does not contain any economic data. Therefore, the Belgian Sea Fishery Service of the Flemish government was addressed. It collects economic data of the Belgian sea fisheries fleet by survey (on a voluntary basis, sample of approximately 65 vessels).

9. Evaluation of the microworld

a. Testing the microworld

Knowing that this microworld is still in a preliminary phase, we ran the microworld (dt = one day, simulation length = 3650 days (10 years)) with as much reliable data as possible (see Annex 2 for the initial values used).

To evaluate the microworld, five output graphs are studied in detail.

- Quota for each fishing ground (1)
- Revenues versus total costs for company 1 (2)
- Revenues versus total costs for company 2 (3)
- Earnings for each company (4)
- Savings for each company (5)

These graphs can be situated in the cells of our output matrix of the preliminary microworld (table 3).

In examining the graph which plots the behaviour of the remaining quota for each fishing ground (figure 3), a normal behaviour is found: the total quota is caught over the course of a year. If the remaining quota drops to zero, the vessels remain in their home ports waiting for new quota. At the beginning of a new year, new initial quota are automatically inserted in the microworld (by means of a pulse function). This approach, however, does not allow adjusting quota during the year.

Further examination of the graph unveils some small unrealistic behaviour. In the real world, companies use all their fishing days (approximately 200), but in this microworld, they do not. The quota (reliable data for the three fishing grounds that represent 89% of the total 2005 Belgian fish quota) are caught in approximately 160 days, before the companies reach their 200 fishing days.

Another unrealistic behaviour is the way in which the quota decrease. Firstly, the highest quota decreases until it reaches the level of the second highest. Then, both decrease simultaneously until the lowest quota is met. Finally, the three quota decrease to zero together. This behaviour is caused by the decision algorithm embedded in the 'fishing'-decision point (see figure 2), which is not realistic at present.

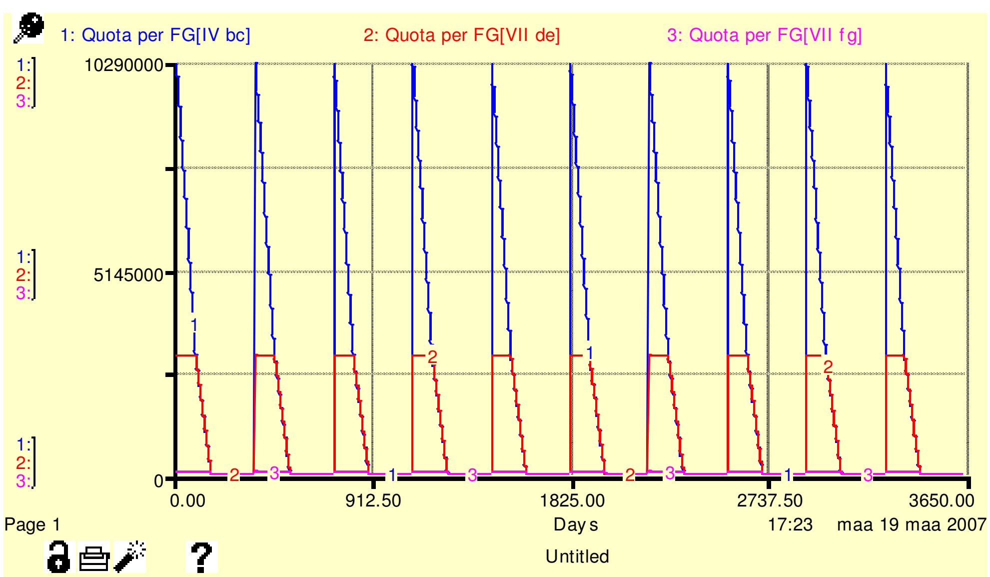

Figure 3 – Output preliminary microworld: Quota dynamics

Next to declining quota, catching fish also results in revenues (sales) and additional variable costs (operating costs) on top of fixed costs[1] for the companies. This process is visualised in figures 4 and 5 for both companies.

During fishing activities, the revenue of company 1 (35 eurocutters) is 91'000 euro per day compared to a total cost of 75'775 euro. When there is no quota left, a fixed cost of 2'100 euro remains. Company 2 (52 large beam trawlers), on the other hand, has 3,5 times the revenue of company 1 on fishing days (322'400 euro), but total costs are also 3,5 times higher (292'240 euro). The fixed costs are also higher for company 2 (7'280 euro).

The outputs of these graphs (figure 4 and 5) illustrate a quite reliable behaviour. The reliability of the behaviour depends on other variables like catch rates (productivity) for revenues and distance to fishing ground for total costs. These variables are still constant in the current microworld, and do not meet the objective of being realistic.

In spite of this critique, the core behaviour of these graphs is already realistic and of some value, mainly due to the impacts of the quota (and fishing days) on the revenues and total costs.

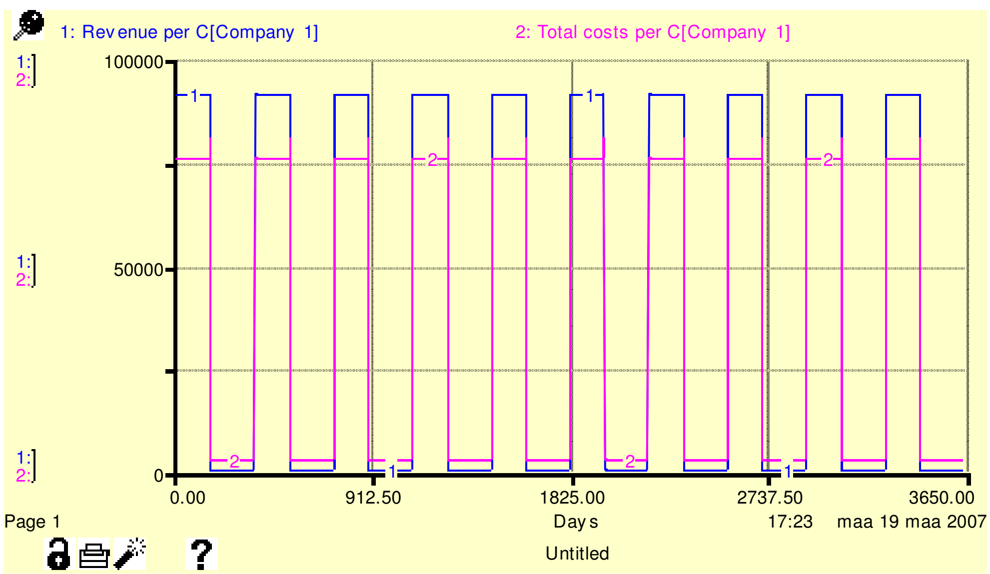

Figure 4 – Output preliminary microworld: Revenues versus total costs company 1

[1] Depreciations are not yet taken into account in this preliminary microworld. The reason is that most of the current Belgian shipping companies and vessels are not profitable any more due to the huge depreciations. This would result in immediate demolition of some vessels in each company from day one; because the disinvestment decision is still based on a threshold value (If savings are < 0 then company sells a vessel).

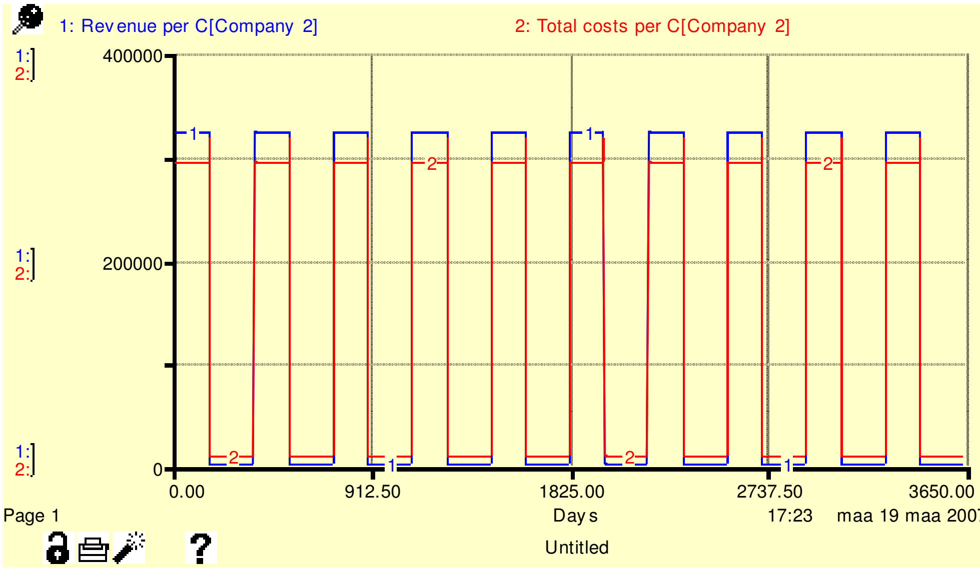

Figure 5 – Output preliminary microworld: Revenues versus total costs company 2

Figure 6 uses the output of figure 4 and 5 to visualise and compare the behaviour of the earnings for each company. The earnings of company 2 (30160 euro) are twice the earnings of company 1 (15225 euro) during fishing days. On non-fishing days, obviously, earnings are negative for both companies.

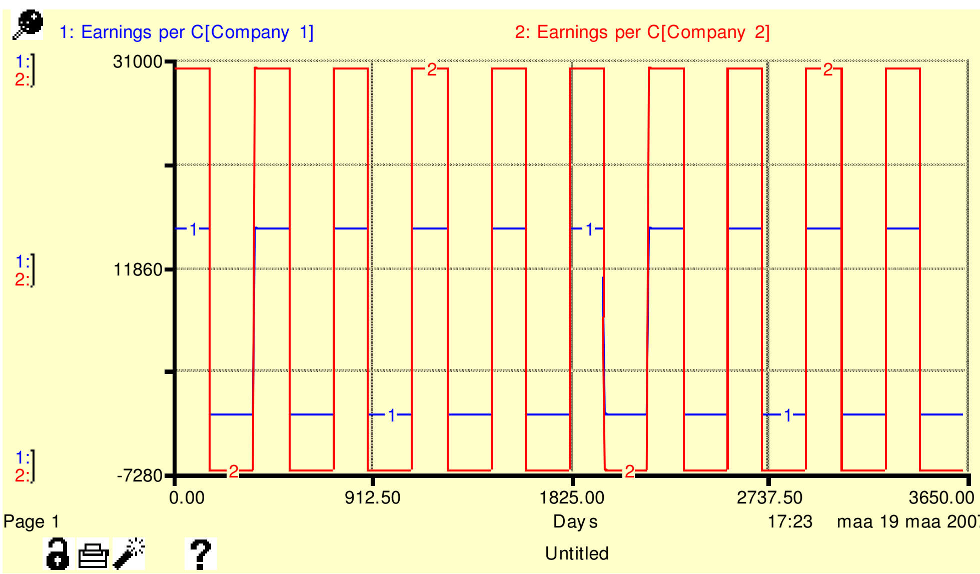

Figure 6 – Output preliminary microworld: Comparing the earning of the two companies.

Earnings per day (positive or negative) contribute to the savings of the companies (figure 7). In the current microworld, the savings of both companies follow a ‘straight line’. Each year, earnings accumulate until the point where the quota drops to zero. Afterwards, fixed costs reduce the savings, until the new quota arrive.

As mentioned before, this (linear) increase in savings per company does not match with reality, since vessel depreciations are not included in the microworld.

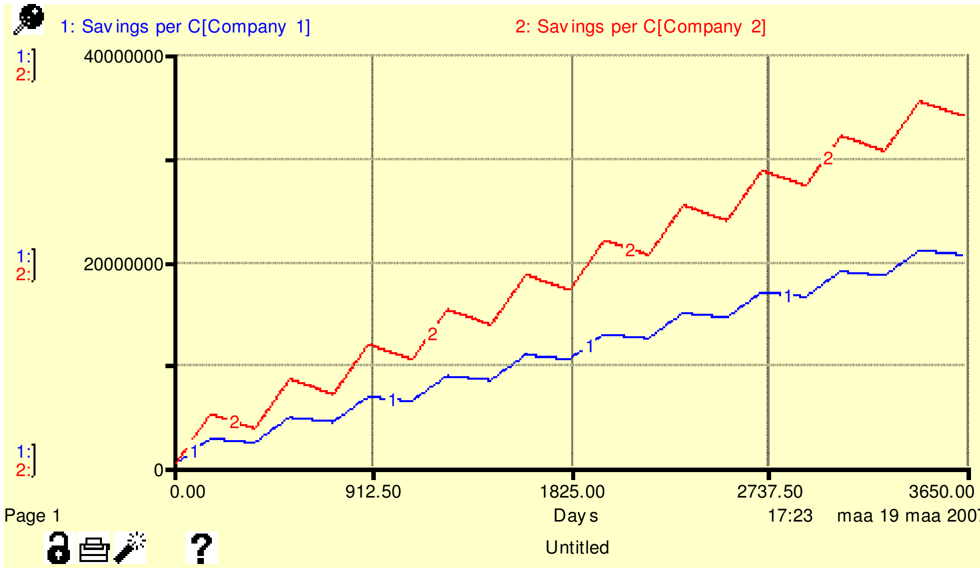

Figure 7 – Output preliminary microworld: Comparing the savings of the two companies.

b. Toward the finalisation of this microworld: The 'to do'-list.

Although the microworld already generates some reliable information, there are still some shortcomings which require further improvement.

Table 6 – Shortcomings of the preliminary microworld and why and how they need to be taken care of.

Shortcoming	Why necessary?	To do
No delays	Delays give rise to (extra) non-linear behaviour in the microworld. It also resembles more the real world in which delays are common.	Include the most important delays in the microworld.
Weak decision points	The two decision points in the preliminary microworld are still based on threshold values and need to be more dynamic and realistic.	There is some interesting literature about these two decision points. Thus, a literature review has to take place. On the other hand, reviewing literature alone will not be sufficient. Contacts with Belgian fisherman are needed to make these decision points more realistic.
Data shortage	Not all the required data to run the microworld are yet available (see annex 2) or included in the	Further data gathering and analyses is needed, and perhaps some data are not known yet (e.g. productivity

	microworld (e.g. depreciations).	of a vessel type per fishing ground).
Quota system	In the preliminary microworld the quota system is too simplified, and is not realistic. The real quota system consists out of more than a quotum for each fishing ground and per target species.	The complexity of the quota system must be integrated in the microworld. This will generate more interesting fleet behaviour.
Fishing days	In the preliminary microworld the system of fishing days is also oversimplified, and is not realistic. The maximum fishing days are normally not only per company, but also per vessel (as a function of the power of the vessel).	Further inquiry in the mechanism of 'maximum fishing days' is needed.
Licenses	The system of licenses is not only a way to control the amount of vessels in the Belgian fleet. It also freezes the composition of the fleet. The latter is not jet included in the preliminary microworld.	The regulations about licenses need to be investigated.
Only one target species	At the moment the microworld only contains one target species (a theoretical average fish). Inserting an array of target species in the microworld illustrates the diversity in catch composition of the different vessel types (e.g. eurocutter catch more 'higher'-priced fish than large beam trawlers). This will have an impact on the revenues of the vessel types, because in the present microworld each fish as the same value.	Insert an array of target species in the microworld.

10. Conclusion

This conference paper offers a preliminary microworld based on a micro-economical approach of fleet dynamics. It will allow policy makers to gain more insight in parameters which can or will influence the Belgian fleet structure. Later on, this microworld should enable testing policies.

Until then, there is still a long journey to be made. Although there is a preliminary microworld, it still contains several shortcomings . Addressing these shortcomings will be the next important step before the validation of the microworld can take place.

This process of building a microworld is and will be an enriching journey. Although the microworld is still in its preliminary stages, our goal is to further develop the microworld taking in account the rules of ‘good modelling practices’. This paper serves as a call for recommendations and dialogue to the conference. The authors are looking forward to constructively improve their current microworld and methodology by means of these comments from the system dynamics society.

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Annexes

Annex 1: The preliminary microworld

Environment
Days_fishing_per_C[Company,Vesseltype](t) = Days_fishing_per_C[Company,Vesseltype](t - dt) + (Yearly_fishing_days[Company,Vesseltype] - Change_in_days[Company,Vesseltype]) * dt
INIT Days_fishing_per_C[Company,Vesseltype] = 200
INFLOWS:
Yearly_fishing_days[Company,Vesseltype] = PULSE(INIT(Days_fishing_per_C[Company,Vesseltype]),365,365)
OUTFLOWS:
Change_in_days[Company,Vesseltype] = IF Count_year < 365 AND Fishing_possible_per_C_per_VT[Company,Vesseltype] = 1 THEN 1 ELSE (IF Count_year = 365 THEN INIT(Days_fishing_per_C[Company,Vesseltype]) ELSE 0)
Quota_per_FG[IV_bc](t) = Quota_per_FG[IV_bc](t - dt) + (Yearly_quota[IV_bc] - Fleet_Catch_per_FG[IV_bc]) * dt
INIT Quota_per_FG[IV_bc] = 10287000
Quota_per_FG[VII_de](t) = Quota_per_FG[VII_de](t - dt) + (Yearly_quota[VII_de] - Fleet_Catch_per_FG[VII_de]) * dt
INIT Quota_per_FG[VII_de] = 2913000
Quota_per_FG[VII_fg](t) = Quota_per_FG[VII_fg](t - dt) + (Yearly_quota[VII_fg] - Fleet_Catch_per_FG[VII_fg]) * dt
INIT Quota_per_FG[VII_fg] = 12597
INFLOWS:
Yearly_quota[Fishing_Ground] = PULSE(INIT(Quota_per_FG[Fishing_Ground]),365,365)
OUTFLOWS:
Fleet_Catch_per_FG[Fishing_Ground] = IF Count_year < 365 THEN ARRAYSUM(Catch_per_C_per_FG[*,Fishing_Ground]) ELSE (IF Count_year = 365 THEN INIT(Quota_per_FG[Fishing_Ground]) ELSE 0)
Catch_per_C_per_FG[Reder_1,IV_bc] = (IF C_choice_per_VT_over_FG[Reder_1,eurocutter] = 1 THEN Productivity_rate_per_VTxFG[eurocutter,IV_bc]*Number_of_vessels_per_C_per_VT[Reder_1,eurocutter] ELSE 0)+(IF C_choice_per_VT_over_FG[Reder_1,large_beam_trawler] = 1 THEN Productivity_rate_per_VTxFG[large_beam_trawler,IV_bc]*Number_of_vessels_per_C_per_VT[Reder_1,large_beam_trawler] ELSE 0)
Catch_per_C_per_FG[Reder_1,VII_de] = (IF C_choice_per_VT_over_FG[Reder_1,eurocutter] = 2 THEN Productivity_rate_per_VTxFG[eurocutter,VII_de]*Number_of_vessels_per_C_per_VT[Reder_1,eurocutter] ELSE 0)+(IF C_choice_per_VT_over_FG[Reder_1,large_beam_trawler] = 2 THEN Productivity_rate_per_VTxFG[large_beam_trawler,VII_de]*Number_of_vessels_per_C_per_VT[Reder_1,large_beam_trawler] ELSE 0)
Catch_per_C_per_FG[Reder_1,VII_fg] = (IF C_choice_per_VT_over_FG[Reder_1,eurocutter] = 3 THEN Productivity_rate_per_VTxFG[eurocutter,VII_fg]*Number_of_vessels_per_C_per_VT[Reder_1,eurocutter] ELSE 0)+(IF C_choice_per_VT_over_FG[Reder_1,large_beam_trawler] = 3 THEN Productivity_rate_per_VTxFG[large_beam_trawler,VII_fg]*Number_of_vessels_per_C_per_VT[Reder_1,large_beam_trawler] ELSE 0)
Catch_per_C_per_FG[Reder_2,IV_bc] = (IF C_choice_per_VT_over_FG[Reder_2,eurocutter] = 1 THEN Productivity_rate_per_VTxFG[eurocutter,IV_bc]*Number_of_vessels_per_C_per_VT[Reder_2,eurocutter] ELSE 0)+(IF C_choice_per_VT_over_FG[Reder_2,large_beam_trawler] = 1 THEN Productivity_rate_per_VTxFG[large_beam_trawler,IV_bc]*Number_of_vessels_per_C_per_VT[Reder_2,large_beam_trawler] ELSE 0)
Catch_per_C_per_FG[Reder_2,VII_de] = (IF C_choice_per_VT_over_FG[Reder_2,eurocutter] = 2 THEN Productivity_rate_per_VTxFG[eurocutter,VII_de]*Number_of_vessels_per_C_per_VT[Reder_2,eurocutter] ELSE 0)+(IF C_choice_per_VT_over_FG[Reder_2,large_beam_trawler] = 2 THEN Productivity_rate_per_VTxFG[large_beam_trawler,VII_de]*Number_of_vessels_per_C_per_VT[Reder_2,large_beam_trawler] ELSE 0)
Catch_per_C_per_FG[Reder_2,VII_fg] = (IF C_choice_per_VT_over_FG[Reder_2,eurocutter] = 3 THEN Productivity_rate_per_VTxFG[eurocutter,VII_fg]*Number_of_vessels_per_C_per_VT[Reder_2,eurocutter] ELSE 0)+(IF C_choice_per_VT_over_FG[Reder_2,large_beam_trawler] = 3 THEN Productivity_rate_per_VTxFG[large_beam_trawler,VII_fg]*Number_of_vessels_per_C_per_VT[Reder_2,large_beam_trawler] ELSE 0)
Catch_per_C_per_subfleet__depending_on_choice_FG[Company,Vesseltype] = (IF C_choice_per_VT_over_FG[Company,Vesseltype] = 1 THEN Productivity_rate_per_VTxFG[Vesseltype,IV_bc] ELSE (IF C_choice_per_VT_over_FG[Company,Vesseltype] = 2 THEN Productivity_rate_per_VTxFG[Vesseltype,VII_de] ELSE (IF C_choice_per_VT_over_FG[Company,Vesseltype] = 3 THEN Productivity_rate_per_VTxFG[Vesseltype,VII_fg] ELSE 0)))*Number_of_vessels_per_C_per_VT[Company,Vesseltype]
Count_year = COUNTER(1,366)
Distance_done_per_c_per_VT[Company,Vesseltype] = IF C_choice_per_VT_over_FG[Company,Vesseltype] = 1 THEN 2*Distance_to_FG[IV_bc] ELSE (IF C_choice_per_VT_over_FG[Company,Vesseltype] = 2 THEN 2*Distance_to_FG[VII_de] ELSE (IF C_choice_per_VT_over_FG[Company,Vesseltype] = 3 THEN 2*Distance_to_FG[VII_fg] ELSE 0))
Distance_to_FG[IV_bc] = 50

Distance_to_FG[VII_de] = 50
Distance_to_FG[VII_fg] = 60
Fish_Price = 5
Fuel_cost_euroKm_per_VT[eurocutter] = Fuel_price_euroL*15
Fuel_cost_euroKm_per_VT[large_beam_trawler] = Fuel_price_euroL*50
Fuel_price_euroL = 0.45
Productivity_rate_per_VTxFG[eurocutter,IV_bc] = 520
Productivity_rate_per_VTxFG[eurocutter,VII_de] = 520
Productivity_rate_per_VTxFG[eurocutter,VII_fg] = 520
Productivity_rate_per_VTxFG[large_beam_trawler,IV_bc] = 1240
Productivity_rate_per_VTxFG[large_beam_trawler,VII_de] = 1240
Productivity_rate_per_VTxFG[large_beam_trawler,VII_fg] = 1240
Traveling_Costs_per_C_per_VT[Company,Vesseltype] =
Distance_done_per_c_per_VT[Company,Vesseltype]*Fuel_cost_euroKm_per_VT[Vesseltype]
Variable_Costs_per_C_per_VT[Reder_1,eurocutter] = if Fishing_possible_per_C_per_VT[Reder_1,eurocutter] = 1 THEN 1430 ELSE 0
Variable_Costs_per_C_per_VT[Reder_1,large_beam_trawler] = if Fishing_possible_per_C_per_VT[Reder_1,large_beam_trawler] = 1 THEN 3230 ELSE 0
Variable_Costs_per_C_per_VT[Reder_2,eurocutter] = IF Fishing_possible_per_C_per_VT[Reder_2,eurocutter] = 1 THEN 1430 ELSE 0
Variable_Costs_per_C_per_VT[Reder_2,large_beam_trawler] = IF Fishing_possible_per_C_per_VT[Reder_2,large_beam_trawler] = 1 THEN 3230 ELSE 0
C goes fishing? And Where?
C_choice_per_VT_over_FG[Company,Vesseltype] = if Fishing_possible_per_C_per_VT[Company,Vesseltype] = 1 THEN FG_with_Max_quota ELSE 0
FG_with_Max_quota = ARRAYMAXIDX(Quota_per_FG[*])
Fishing_possible_per_C_per_VT[Company,Vesseltype] = If ARRAYMAX(Quota_per_FG[*])>0 AND Fish_Price > 0 AND Days_fishing_per_C[Company,Vesseltype]>0 THEN 1 ELSE 0

Finances per Company
Savings_per_C[Company](t) = Savings_per_C[Company](t - dt) + (Earnings_per_C[Company] - Investment_per_C[Company]) * dt
INIT Savings_per_C[Company] = 100
INFLOWS:
Earnings_per_C[Company] = Revenue_per_C[Company]-Total_costs_per_C[Company]
OUTFLOWS:
Investment_per_C[Company] = Financial_result_Investment_decision_per_C[Company]
Catch_per_C[Company] = ARRAYSUM(Catch_per_C_per_subfleet__depending_on_choice_FG[Company,*])
Fixed_Costs_per_C_per_VT[Reder_1,eurocutter] = 60
Fixed_Costs_per_C_per_VT[Reder_1,large_beam_trawler] = 140
Fixed_Costs_per_C_per_VT[Reder_2,eurocutter] = 60
Fixed_Costs_per_C_per_VT[Reder_2,large_beam_trawler] = 140
Revenue_per_C[Company] = Catch_per_C[Company]*Fish_Price
Total_costs_per_C[Company] = ARRAYSUM(Total_Costs_per_C_per_VT[Company,*])
Total_Costs_per_C_per_VT[Reder_1,eurocutter] =
(Fixed_Costs_per_C_per_VT[Reder_1,eurocutter]+Traveling_Costs_per_C_per_VT[Reder_1,eurocutter]+Variable_Costs_per_C_per_VT[Reder_1,eurocutter])*Number_of_vessels_per_C_per_VT[Reder_1,eurocutter]
Total_Costs_per_C_per_VT[Reder_1,large_beam_trawler] =
(Fixed_Costs_per_C_per_VT[Reder_1,large_beam_trawler]+Traveling_Costs_per_C_per_VT[Reder_1,large_beam_trawler]+Variable_Costs_per_C_per_VT[Reder_1,large_beam_trawler])*Number_of_vessels_per_C_per_VT[Reder_1,large_beam_trawler]
Total_Costs_per_C_per_VT[Reder_2,eurocutter] =
(Fixed_Costs_per_C_per_VT[Reder_2,eurocutter]+Traveling_Costs_per_C_per_VT[Reder_2,eurocutter]+Variable_Costs_per_C_per_VT[Reder_2,eurocutter])*Number_of_vessels_per_C_per_VT[Reder_2,eurocutter]
Total_Costs_per_C_per_VT[Reder_2,large_beam_trawler] =
(Fixed_Costs_per_C_per_VT[Reder_2,large_beam_trawler]+Traveling_Costs_per_C_per_VT[Reder_2,large_beam_trawler]+Variable_Costs_per_C_per_VT[Reder_2,large_beam_trawler])*Number_of_vessels_per_C_per_VT[Reder_2,large_beam_trawler]

Fleet dynamics
Licenses(t) = Licenses(t - dt) + (Change_lic) * dt
INIT Licenses = 100
INFLOWS:
Change_lic = ARRAYSUM(Changes_in_number[*,*])
Number_of_vessels_per_C_per_VT[Reder_1,eurocutter](t) = Number_of_vessels_per_C_per_VT[Reder_1,eurocutter](t - dt) + (Changes_in_number[Reder_1,eurocutter]) * dt
INIT Number_of_vessels_per_C_per_VT[Reder_1,eurocutter] = 35

Number_of_vessels_per_C_per_VT[Reder_1,large_beam_trawler](t) =
Number_of_vessels_per_C_per_VT[Reder_1,large_beam_trawler](t - dt) +
(Changes_in_number[Reder_1,large_beam_trawler]) * dt
INIT Number_of_vessels_per_C_per_VT[Reder_1,large_beam_trawler] = 0
Number_of_vessels_per_C_per_VT[Reder_2,eurocutter](t) = Number_of_vessels_per_C_per_VT[Reder_2,eurocutter](t - dt) +
(Changes_in_number[Reder_2,eurocutter]) * dt
INIT Number_of_vessels_per_C_per_VT[Reder_2,eurocutter] = 0
Number_of_vessels_per_C_per_VT[Reder_2,large_beam_trawler](t) =
Number_of_vessels_per_C_per_VT[Reder_2,large_beam_trawler](t - dt) +
(Changes_in_number[Reder_2,large_beam_trawler]) * dt
INIT Number_of_vessels_per_C_per_VT[Reder_2,large_beam_trawler] = 52
INFLOWS:
Changes_in_number[Company,Vesseltype] = IF Licenses >0 THEN Investment_per_C_per_VT[Company,Vesseltype] ELSE 0
Financial_result_Investment_decision_per_C[Reder_1] = (IF Investment_per_C_per_VT[Reder_1,eurocutter] = 1 THEN
Price_for_a_vessel_per_VT[eurocutter,Buying] ELSE (IF Investment_per_C_per_VT[Reder_1,eurocutter] = -1 THEN -
(Price_for_a_vessel_per_VT[eurocutter,Selling]) ELSE 0))+(IF Investment_per_C_per_VT[Reder_1,large_beam_trawler] = 1
THEN Price_for_a_vessel_per_VT[large_beam_trawler,Buying] ELSE (IF
Investment_per_C_per_VT[Reder_1,large_beam_trawler] = -1 THEN -
(Price_for_a_vessel_per_VT[large_beam_trawler,Selling]) ELSE 0))
Financial_result_Investment_decision_per_C[Reder_2] = (IF Investment_per_C_per_VT[Reder_2,eurocutter] = 1 THEN
Price_for_a_vessel_per_VT[eurocutter,Buying] ELSE (IF Investment_per_C_per_VT[Reder_2,eurocutter] = -1 THEN -
(Price_for_a_vessel_per_VT[eurocutter,Selling]) ELSE 0))+(IF Investment_per_C_per_VT[Reder_2,large_beam_trawler] = 1
THEN Price_for_a_vessel_per_VT[large_beam_trawler,Buying] ELSE (IF
Investment_per_C_per_VT[Reder_2,large_beam_trawler] = -1 THEN -
(Price_for_a_vessel_per_VT[large_beam_trawler,Selling]) ELSE 0))
Price_for_a_vessel_per_VT[eurocutter,Buying] = 2100000
Price_for_a_vessel_per_VT[eurocutter,Selling] = 500000
Price_for_a_vessel_per_VT[large_beam_trawler,Buying] = 5000000
Price_for_a_vessel_per_VT[large_beam_trawler,Selling] = 1100000
Investment decision
Investment_per_C_per_VT[Reder_1,eurocutter] = IF Possible_to_invest_per_C_per_VT[Reder_1,eurocutter] = 1 AND
Investment_preference_VT_per_C[Reder_1,Buying] = 1 THEN 1 ELSE (IF
Possible_to_invest_per_C_per_VT[Reder_1,eurocutter] = -1 AND Investment_preference_VT_per_C[Reder_1,Selling] = 1
THEN -1 ELSE 0)
Investment_per_C_per_VT[Reder_1,large_beam_trawler] = IF Possible_to_invest_per_C_per_VT[Reder_1,large_beam_trawler] = 1
AND Investment_preference_VT_per_C[Reder_1,Buying] = 2 THEN 1 ELSE (IF
Possible_to_invest_per_C_per_VT[Reder_1,large_beam_trawler] = -1 AND
Investment_preference_VT_per_C[Reder_1,Selling] = 2 THEN -1 ELSE 0)
Investment_per_C_per_VT[Reder_2,eurocutter] = IF Possible_to_invest_per_C_per_VT[Reder_2,eurocutter] = 1 AND
Investment_preference_VT_per_C[Reder_2,Buying] = 1 THEN 1 ELSE (IF
Possible_to_invest_per_C_per_VT[Reder_2,eurocutter] = -1 AND Investment_preference_VT_per_C[Reder_2,Selling] = 1
THEN -1 ELSE 0)
Investment_per_C_per_VT[Reder_2,large_beam_trawler] = IF Possible_to_invest_per_C_per_VT[Reder_2,large_beam_trawler] = 1
AND Investment_preference_VT_per_C[Reder_2,Buying] = 2 THEN 1 ELSE (IF
Possible_to_invest_per_C_per_VT[Reder_2,large_beam_trawler] = -1 AND
Investment_preference_VT_per_C[Reder_2,Selling] = 2 THEN -1 ELSE 0)
Investment_preference_VT_per_C[Reder_1,Buying] = IF Number_of_vessels_per_C_per_VT[Reder_1,large_beam_trawler] <= 0 THEN
2 ELSE 1
Investment_preference_VT_per_C[Reder_1,Selling] = IF Number_of_vessels_per_C_per_VT[Reder_1,large_beam_trawler] > 0 THEN
2 ELSE 1
Investment_preference_VT_per_C[Reder_2,Buying] = IF Number_of_vessels_per_C_per_VT[Reder_2,eurocutter] <= 0 THEN 1 ELSE
2
Investment_preference_VT_per_C[Reder_2,Selling] = IF Number_of_vessels_per_C_per_VT[Reder_2,eurocutter] > 0 THEN 1 ELSE 2
Possible_to_invest_per_C_per_VT[Company,Vesseltype] = IF Savings_per_C[Company] > 250000000 THEN 1 ELSE (IF
Savings_per_C[Company] <= 0 AND Number_of_vessels_per_C_per_VT[Company,Vesseltype] >0 THEN -1 ELSE 0)

Not in a sector

Annex 2: Data used for running the preliminary microworld

Table 7 – Data used to run the preliminary microworld (VT = Vessel type, FG = Fishing ground and TS = Target Species)

Variable			Initial Value	Unit of measurement	Data source*
Quota	FG IVbc		10’287’000	Kg	SF
	FG IIVde		2’913’000	Kg	SF
	FG IIVfg		1’096’000	Kg	SF
Fishing days	For each Company		200	Day	Fictive
Licenses			100	License	Fictive
Number of vessel per company	Company 1	Eurocutters	**35	Vessel	Fictive
		Large Beam trawlers	0	Vessel	Fictive
	Company 2	Eurocutters	0	Vessel	Fictive
		Large Beam trawlers	***52	Vessel	Fictive
Productivity rate	Eurocutters	FG IVbc	520	Kg/day	Fictive
		FG IIVde	520	Kg/day	Fictive
		FG IIVfg	520	Kg/day	Fictive
	Large beam trawlers	FG IVbc	1’240	Kg/day	Fictive
		FG IIVde	1’240	Kg/day	Fictive
		FG IIVfg	1’240	Kg/day	Fictive
Fish price	Average TS		5	Euro/fish	SF
Distance to FG	FG IVbc		40	Km/day	ILVO
	FG IIVde		40	Km/day	ILVO
	FG IIVfg		80	Km/day	ILVO
Fuel price			0,45	Euro/L	SF
Variable costs	Company 1	Eurocutter	1’430	Euro/day	SF
		Large beam trawler	3’230	Euro/day	SF
	Company 2	Eurocutter	1’430	Euro/day	SF
		Large beam trawler	3’230	Euro/day	SF
Fixed costs	Company 1	Eurocutter	60	Euro/day	SF
		Large beam trawler	140	Euro/day	SF
	Company 2	Eurocutter	60	Euro/day	SF
		Large beam trawler	140	Euro/day	SF
Price for a vessel	Eurocutter	Buying	2’100’000	Euro	ILVO
		Selling	500’000	Euro	ILVO
	Large beam trawler	Buying	5’000’000	Euro	ILVO
		Selling	1’100’000	Euro	ILVO

*Data source: (1) Belgian Sea Fisheries Service = ‘SF’, (2) Internal data Institute for Agriculture and Fisheries Research = ‘ILVO’ (3) Fictive data = ‘fictive’.
** Number of eurocutters in 2005
*** Number of Large beam trawlers in 2005