FACULTEIT ECONOMIE EN BEDRIJFSKUNDE
DEP. OF MANAGEMENT, INNOVATION AND ENTREPRENEURSHIP

Learning from a microworld in fisheries management

The Belgian fisheries system

Hendrik Stouten

2010

Dissertation submitted to the Faculty of Economics and Business Administration,
Ghent University, in partial fulfillment of the requirements for the degree of
Doctor in Applied Economic Sciences

Voor Sanne, mijn hopelijk toekomstig vrouwtje!

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“Most paradigm changes occur at funerals”

Peter Senge (1997: 130)

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Hendrik Stouten
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Summary

One of the key research questions in organisational learning is: “How can organisations become better at double-loop learning?”. This research question has invited scholars to find ways of (1) enhancing individual double-loop learning, and of (2) sharing these altered individual mental models throughout the organisation. To accomplish these goals the literature proposes many tools, such as simulation, role plays, and dialogue and discussion. The application of microworlds, simulation models that are locked by user-friendly interfaces, is one of them. Microworlds are used as learning laboratories for ex ante evaluation of possible policy strategies. They also serve the purpose of being a transitional object in which strategies are rehearsed and visualised bringing them into debate and discussion. A strong belief exists that some form of “learning” occurs when using microworlds. Nevertheless, this belief generates widespread disagreement within several scientific communities. The main reason for this disagreement is the absence of a well-structured body of evaluation research that examines whether any valuable “learning” takes place from using microworlds.

This study investigates to what extent learning takes place from a self-developed microworld in the field of fisheries management based on the Belgian fisheries system. It describes the process of developing a microworld in which fisheries policy initiatives can be visualised and rehearsed. It first determines whether the theory of strategic groups is relevant for the Belgian fishing fleet. These findings are then used to develop a microworld in which stakeholders can discover the long term effects that policy instruments may have on the Belgian fisheries system. This makes the microworld a useful instrument to test whether policymakers have the policy instruments at their disposal to align the real fisheries system with their desired one. Because this microworld has been developed following a “create-and-share”-approach, the last part of this thesis is about reaching and informing a group larger than the model development team about its outcomes. This is done, in tandem with a true experiment in which we test if stakeholders in the Belgian fisheries system actually learn from our microworld. Such a test of learning is seen as the ultimate criterion for assessing the validity of microworlds.

Our study cannot conclude that decision makers learn from playing with microworlds. This suggests that more work is needed to fully realise the potential of microworlds in learning processes, yet researchers are left with little guidance on how to develop an effective “learning system”. Our most valuable guideline for future evaluation research is to start testing which features of microworlds, “users” and “situations”, are essential for learning from microworlds. Crucial in this kind of future evaluation research is to apply “before-after with control group”-designs in which the experimental group only differs from the control group by exactly one characteristic of the microworld, users or environmental context. Finally, future evaluation research should also start adopting a “process-based approach” in which it aims to provide insights into the actual processes or mechanisms that explain learning effects from microworlds.

Samenvatting

Eén van de belangrijkste onderzoeksvragen in organisationeel leren is: “Hoe kunnen organisaties beter worden in dubbel-loop leren?”. Deze onderzoeksvraag heeft wetenschappers aangezet manieren te vinden om (1) individueel dubbel-loop leren te bevorderen, en om (2) gewijzigde individuele mentale modellen te delen binnen organisaties. Om deze doelstellingen te verwezelijken stelt de literatuur talrijke instrumenten voor zoals simulatie, rollenspellen, en dialoog en discussie. Het gebruik van microworlds, simulatie modellen omsloten met een gebruiksvriendelijke interface, is er hier dus één van. Microworlds worden gebruikt als leer-laboratoria voor ex ante evaluatie van mogelijke beleidsstrategieën. Daarnaast fungeren ze ook als “bindingsobjecten” waarmee strategieën gerepeteerd en gevisualiseerd kunnen worden om deze zo te onderwerpen aan debat en discussie. Er heerst een sterk geloof dat een vorm van “leren” zich voordoet bij het gebruik van microworlds. Desondanks blijft hierover onenigheid bestaan in verscheidene wetenschappelijke gemeenschappen. De belangrijkste reden voor deze onenigheid is het gebrek aan een goed gestructureerde geheel van evaluatieonderzoek dat nagaat of enig waardevol “leren” zich voordoet bij het gebruik van microworlds.

Deze thesis onderzoekt in welke mate leren plaats grijpt uit een zelfgemaakte microworld met betrekking tot visserijmanagement gebaseerd op het Belgisch visserijsysteem. Het beschrijft het ontwikkelingsproces van een microworld waarin visserijbeleidsinitiatieven kunnen gevisualiseerd en gerepeteerd worden. Het beslist echter eerst of de theorie van strategische groepen relevant is voor de Belgische vissersvloot. Deze bevindingen worden dan meegenomen in het ontwikkelen van een microworld waarin stakeholders de langetermijneffecten kunnen nagaan die beleidsinstrumenten kunnen hebben op het Belgische visserijsystem. Dit maakt de microworld een geschikt instrument om te achterhalen of beleidsmakers de beleidsinstrumenten ter beschikking hebben om het bestaande visserijsysteem af te stemmen op dat van hun wensen. Omdat de microworld ontwikkeld is via een “creëer-en-deel”-benadering heeft het laatste deel van deze thesis betrekking op het bereiken en informeren van een groep groter dan de groep die mee heeft geholpen de microworld te ontwikkelen. Dit wordt gekoppeld aan een waarachtig experiment waarin wordt gekeken of stakeholders in het Belgische visserijsystem effectief leren uit onze microworld. Een dergelijke test naar leereffecten wordt aanzien als het ultieme criterium om de validiteit van microworlds te bepalen.

Onze studie kan weliswaar niet concluderen dat besluitvormers leren door met microworlds te spelen. Dit suggereert dat meer werk nodig is om het potentieel van microworlds in leerprocessen volledig te realiseren. Onderzoekers geven elkaar echter weinig advies over hoe efficiënte leersystemen te ontwikkelen. Onze meest waardevolle richtlijn voor toekomstig evaluatieonderzoek is het opstarten van onderzoek dat nagaat welke kenmerken van microworlds, “gebruikers” en “situaties” essentieel zijn voor leren uit microworlds. Cruciaal in dit type van toekomstig evaluatieonderzoek is het toepassen van een “vóór-na met controle groep”-design waarbij de experimentele groep enkel verschilt van de controle groep in exact één karakteristiek van de microworld, gebruiker of omgeving. Ten laatste zou toekomstig evaluatie onderzoek zich moeten focussen op een “proces-gebaseerde aanpak” waarbij het doel is inzichten verschaffen in de werkelijke processen en mechanismen die leereffecten van microworlds kunnen verklaren.

Photo: Members of the European Commission playing with my microworld (©Annemie Schollaert – ILVO)

Chapter 1: General introduction: research questions, framework and design

Microworlds, a specific form of simulation models, have been referred to as (1) insight generators (Morecroft, 1984), (2) tools for inquiry into dynamic decision-making processes (Brehmer, 2005; Gonzalez *et al.*, 2005), (3) tools to visualise and rehearse decisions and strategies (Morecroft, 1999; Morecroft, 1984), (4) tools to debate and discuss strategies (Morecroft, 1999; Morecroft, 1984), (5) laboratories for ex ante evaluation of decision making (De Geus, 1997; Keys *et al.*, 1996), (6) learning laboratories (Kim, 1993b; Romme *et al.*, 1997), (7) learning environments (Wolfe, 1976), (8) learning spaces (Senge, 1996), and (9) educational tools (Sindre *et al.*, 2009). In other words, various scientists believe, explicitly or implicitly, that some form of "learning" occurs when using microworlds. Nevertheless, this belief still generates widespread disagreement within several scientific communities (Bakken *et al.*, 1994; Bell *et al.*, 2008; Cavaleri *et al.*, 1996; Langley, 1993; Langley *et al.*, 1996). The main reason for this disagreement is the absence of a well-structured body of evaluation research that examines whether any valuable "learning" actually takes place from the use of microworlds (Akili, 2007; Bakken *et al.*, 1994; Bell *et al.*, 2008; Cavaleri *et al.*, 1997; Gosen *et al.*, 2004; Gresse von Wangenheim *et al.*, 2009; Huz *et al.*, 1997; Raia, 1966; Sweeney *et al.*, 2000; Tonks *et al.*, 1997; Wolfe, 1976). The lack of structure in this body of evaluation research is unjustified and causes problems for future research on the application of microworlds in learning processes. It is thus vital to perform more structured evaluation research.

I have identified this research problem in the context of the collaboration between the Institute for Agriculture and Fisheries Research (ILVO)[1] and Ghent University[2]. This problem is crucial for ILVO, since it is planning to use microworlds to formulate a long-term strategy for the Belgian fisheries system (Polet *et al.*, 2006). ILVO will use microworlds as learning laboratories for ex ante evaluation of possible policy strategies (De Geus, 1997; Keys *et al.*, 1996). Additionally, they will also serve the purpose of being a transitional object in which strategies are rehearsed and visualised (Morecroft, 1999) bringing them into debate and discussion (Morecroft, 1984) among members of ILVO and other stakeholder groups. The objectives of this thesis will help chart the new course ILVO is sailing, by (1) developing a microworld in which stakeholders of the Belgian fisheries system can "play" and gain long-term insights in the effect policy instruments have on the Belgian fisheries system (i.e., fisheries management), (2) informing a group larger than the model development team about the outcome of the microworld (i.e., the "create-and-share"-approach (Kreutzer, 1995: 218)), and related to this (3) evaluating if stakeholders in the Belgian fisheries system actually learn from the developed microworld through a strictly controlled experimental design.

[1] www.ilvo.vlaanderen.be
[2] www.ugent.be

1.1 Theory and conceptual framework

The conceptual framework outlined below describes our approach to investigate learning from microworlds in fisheries management. It starts with explaining the underlying theory of learning at both the individual and organisational level. It also defines "microworlds" and states where they fit in the individual and organisational learning processes.

1.1.1 Individual learning

Psychologists, linguists, educators, and others have heavily researched the topic of learning at the individual level (Kim, 1993b). Numerous theories about the way humans learn have been proposed, debated and tested (e.g., Hergenhahm *et al.*, 1993; Hilgard *et al.*, 1966). However, despite all this research, relatively little is known about the human mind and the learning process (Kim, 1993b). Moreover, until the 1970s (former behavioural theories), learning was commonly defined as a *product* - a change in behaviour. It was the outcome of some process. However, over the following decades, this product-oriented definition was changed toward a *process*-oriented definition (Kim, 1993a). Despite this long-lasting tendency to see learning as a product, John Dewey had already described learning as a *feedback* process in the beginning of the 20th century. He depicted learning as an iterative cycle of inventions, observations, reflection and action (Schön, 1992). This iterative cycle evolved over the years and appeared in many forms in a variety of research fields using different terms, but it always visualized the same underlying feedback process (Altman *et al.*, 1998; Garvin, 2000). For instance, in total quality management literature, it showed up as the Shewhart-Deming-cycle of Plan-Do-Check/Study-Act or PDCA (Landesberg, 1999; Sterman, 2000). In organisational development, the Schein's cycle of Observation, emotional Reaction, Judgment, and Intervention (ORJI-cycle) is observed (Schein, 1987, 1988) whereas in action science, Argyris and Schön (1978) used a Discovery-Intervention-Production-Generalization cycle of learning. In organisational learning theory, Kim (1993a; 1993b) refers to Kofman's version of the learning cycle: the Observe-Assess-Design-Implement (OADI) cycle. Finally, others call this cycle "the wheel of learning" consisting of Questions-Ideas-Tests-Reflections (Handy, 1995) and Vogt (1995) refers to this learning cycle as the Observe-Reflect-Abstract-Experiment-cycle. Consequently, the process-oriented definition of learning is now widely agreed upon by scholars and serves as a basis for its many working definitions. In fact, most scholars define learning as "a process that unfolds over time and links it with knowledge acquisition, deeper understanding, and improved performance" (Garvin, 2000: 9). However, there is still no generally accepted definition of learning since its meaning varies widely with the context (Garvin, 2000; Kim, 1993a).

It is important to be clear that learning is distinct from memory because "learning has more to do with *acquisition*, whereas memory has more to do with *retention* of whatever was acquired" (Kim, 1993b: 39). Powers (1973: 205) defines memory as "the storage and retrieval of information carried by neural signals" and draws an analogy to computer memory. These storage and retrieval processes are also prominent in other definitions of memory. For instance, Miller et al. (1960) see memory as "plans for retrieval", without which storage would be meaningless, whereas Anderson (1983) divides memory into three types: (1) declarative memory, which contains permanent records that have been stored for retrieval, (2) working memory, which is basically declarative memory that has been retrieved from active use and (3) production memory, which is engaged when an action is being executed. However, each of these views on memory misses the active role memory plays in the learning process because what a person already has in this memory affects what he learns and what he learns affects his memory (Ayas *et al.*, 1996a; Kim, 1993b; Walsh *et al.*, 1991). This interaction between learning and memory is fundamental to individual learning because "learning without memory would require relearning everything as if it were the first time, while memory without learning would be like a storage drum with no inflow whose usefulness decays over time" (Kim, 1993a: 51). As a result, one must make a distinction between "stored" memory and "active" structures that affect an individual's thinking process. This thesis follows Senge's (1990), Kim's (1993a) and Ayas and Foppen's (1996a) views by referring to these active structures as an individual's *mental models*.

Mental models are widely discussed in psychology and philosophy (e.g., Gentner *et al.*, 1983). Different theorists describe mental models as "collections of routines or standard operating procedures, scripts for selecting possible actions, cognitive maps of the domain, the typologies for categorizing experience, logical structures for the interpretation of language, or attributions about individuals who encounter in daily life" (Sterman, 2000: 16). As a result, the concept of mental models differs from the traditional notion of memory as static storage because "they play an active role in what an individual sees and does" (Kim, 1993a: 53). In fact, Senge (1990: 174) defines mental models as "deeply held internal images of how the world works". Hence, mental models represent a person's view of the world, including both implicit and explicit understandings. They function as a *context* for viewing and interpreting new information, and they determine how stored information is relevant to a given situation. Kim (1993b: 39) makes the comparison with a computer's source code and states: "they are like a source code of a computer's operating system, the manager and arbiter of acquiring, retaining, using, and deleting new information. But they are also much more than that because they are also like the programmer of that source code with the know-how to design a different source code as well as the know-why to choose one over the other."

Including individual mental models in the working definition of learning allows distinguishing different levels of learning which can be seen as "a hierarchy based on the level of insight and association building" (Fiol *et al.*, 1985: 807). Although these levels of learning are "progressively more difficult to attain and can be associated with improving the quality of learning" (Ayas *et al.*, 1996b: 52), each level of learning can be optimal depending on the situation in which the decision maker finds him- or herself (Argyris, 1977; Argyris *et al.*, 1978). Perhaps the most commonly known distinction is the one between single- and double-loop learning (Argyris *et al.*, 1978; Sterman, 2000). Others have also made this distinction but labelled it as (1) habit-forming versus discovery learning (Hedberg *et al.*, 1976), (2) reactive versus proactive learning (Miles *et al.*, 1980), (3) lower-level learning versus higher-level learning (Fiol *et al.*, 1985), (4) behavioural level and strategy level learning (Duncan, 1974; Dutton *et al.*, 1987), (5) operational versus conceptual learning (Kim, 1993a, 1993b), (6) adaptive versus generative learning (Senge, 1990), (7) tactical versus strategic learning (Dodgson, 1991, 1993), and (8) learning at the level of "rules" versus at the level of "insights" (Swieringa *et al.*, 1992). *Single-loop* learning is the learning process in which "decision makers compare information about the state of the real system to various goals, perceive discrepancies between desired and actual states, and take actions that (they believe) will cause the real world to move towards the desired state" (Sterman, 2000: 15). However, information feedback about the real world is not the only input on which decision-making is based, since decision-making is also the result of strategies and decision rules founded in the mental models of the decision makers. In *double-loop learning*, information feedback about the real world not only alters decisions within the context of existing strategies and decision rules, but also feeds back to alter mental models. As mental models change, strategies and decision rules become revised and therefore the same information processed and interpreted by a different decision rule now yields a different decision (Sterman, 2000). However, besides single- and double-loop learning, the literature also distinguishes between zero-learning (Romme *et al.*, 1999) and deutero-learning (Argyris *et al.*, 1978; Visser, 2003) or what Romme et al., (1999) calls triple-loop learning and Swieringa and Wierdsma (1992) refer to as learning at the level of "principles". *Zero-learning* occurs when decision makers perceive discrepancies between desired and actual states of the world but fail to take corrective actions. Similarly, but at the organisational level, Romme (1999: 439) states that zero-learning occurs in organisations when "fresh imperatives or problems arise, yet members fail to take corrective action". *Deutero-learning* is the ability to learn about how to carry out single- and double-loop learning. It is "learning to learn" or "second-order learning" (Argyris *et al.*, 1978). This study examines only single- and double loop learning.

Up to this point, learning has been discussed at the individual level in which the individual decision maker acts in complete isolation. However, in reality, this is never the case since the individual is influenced by the broader institutional/organisational environment in which he or she operates. One must then examine organisational learning theory and the link between individual learning and organisational learning.

1.1.2 Organisational learning

Organisational learning was introduced in the 1960s (e.g., Cangelosi *et al.*, 1965) and is still a young research field. Research on organisational learning "gained momentum through the publication of *The Fifth Discipline* by Peter Senge (1990) from the Sloan School of Management (MIT), and the special edition on organizational learning in *Organization Science* (1991)" (Romme *et al.*, 1997: 68). The concept of organisational learning has been taken from the psychological concept of individual learning (Weick, 1991). It follows that a substantial part of its theory is based primarily on observations of learning individuals (Huber, 1991; Kim, 1993b; Sterman, 1989). Nevertheless, clear "distinctions must be made between individual and organisational learning" (Fiol *et al.*, 1985: 804). The topic of organisational learning has gained a lot of attention in recent years, but there is still little agreement on what is meant by organisational learning (Garvin, 2000; Kim, 1993b). The literature shows two current approaches in defining the concept of organisational learning, which Romme and Dillen (1997) refer to as normative versus descriptive definitions. The *normative* definition refers to certain requirements an organisation must satisfy in order to be known as a "learning organisation" (e.g., Bomers, 1989; Garvin, 1993; Hayes, 1988; Kline *et al.*, 1993; Senge, 1990) while the *descriptive* approach stresses that organisational learning is a process analogous to the individual learning process (Table 1.1). This thesis follows the descriptive approach to organisational learning.

Table 1.1: An overview of descriptive definitions of organisational learning

Reference	Descriptive definitions of organisational learning
(Argyris, 1977)	Organisational learning is the process of detecting and correcting error.
(Daft *et al.*, 1984)	Organisational learning is defined as the process by which knowledge about action-outcome relationships between the organisation and the environment is developed.
(Fiol *et al.*, 1985)	Organisational learning means the process of improving actions through better knowledge and understanding.
(Levitt *et al.*, 1988)	Organisations are seen as learning by encoding inferences from history into routines that guide behaviour.
(Stata, 1989)	Organisational learning occurs through shared insights, knowledge, and mental models ... *[and]* builds on past knowledge and experience - that is, on memory.
(Huber, 1991)	An entity learns if, through its processing of information, the range of potential behaviours is increased.
(Kim, 1993b)	Organisational learning is defined as increasing an organisation's capacity to take effective action.

(Source: Own compilation, adapted from Garvin, 2000: 10)

The relationship between individual learning and organisational learning is *paradoxical* (Argyris, 1993; Argyris *et al.*, 1978; Bomers, 1989; Huber, 1991; Kim, 1993a; Romme *et al.*, 1997; Senge, 1990), or as Kim (1993b: 37) puts it: "obvious and subtle". Obvious because all organisations are composed of individuals and therefore individual learning is an important and necessary condition of organisational learning. Subtle, since the organisation is capable of learning independent of any single individual, but not independent of all individuals (Argyris *et al.*, 1978; Kim, 1993b; Romme *et al.*, 1997). Consequently, individual learning is important to organisations, but organisational learning is not simply the sum of each members' learning (Dodgson, 1993; Fiol *et al.*, 1985; Kim, 1993b; Kline *et al.*, 1993; Liebowitz, 2000) because organisations influence the learning of their members and store that which has been learned. Consequently, similar to individuals having a memory, organisations also have cognitive systems and memories through which certain modes of behaviour, mental models, norms and values are acquired, retained and shared (Altman *et al.*, 1998; Daft *et al.*, 1984; Garvin, 2000; Hedberg, 1981; Liebowitz, 2000; Thompson, 1995; Weintraub, 1995). The aggregation of these cognitive systems and memories are often referred to as "*organisational memory*" (Walsh *et al.*, 1991). Since organisational memory is analogous to individual memory, it also consists of "stored memory" and "active structures", of which the latter affects a member's individual mental models and are therefore commonly referred to as *shared mental models* (Kim, 1993b).

Shared mental models consist of (1) *organisational routines* including standard operating procedures, and (2) an organisation's world view in the form of shared frameworks or what Kim (1993b: 42) refers to as "*weltanschauungen*". Organisational routines have a tremendous impact on individual learning since they are "commonly accepted practices and procedures that are uniform, unvarying, and performed without thinking" (Garvin, 2000: 19). Levitt and March (1988: 320) refer to them as "the experiential lessons of history" that improve the organisation's efficiency through standardisation, saving time and effort (Garvin, 2000: 20). They are in line with the organisations' shared frameworks or "*weltanschauungen*" and therefore "serve stability and preserve status quo instead of promoting change and reforms" (Ayas *et al.*, 1996b: 55). As such, performing organisational routines can be defined as *organisational single-loop learning* (Kim, 1993a, 1993b). However, there is also a downside to performing organisational routines since they can lead to crises (Weintraub, 1995) frequently related to the notions of (1) "skilled incompetence" (Argyris, 1986, 1996), (2) "competency traps" (Levitt *et al.*, 1988), (3) "core rigidities" (Leonard-Barton, 1992), (4) "defensive routines" (Argyris, 1985), and (5) "paradigm paralysis" (Marshall *et al.*, 1995). However, especially if such crises occur, there are opportunities for members of the organisation to get involved in individual double-loop learning (Argyris, 1977; Romme *et al.*, 1997). At that moment, there is an opportunity for the organisation to absorb individual learning into their shared mental models. This shifts the learning from the individual to the organisational level, commonly referred to as *organisational double-loop learning* (Kim, 1993a, 1993b). However, the literature states that altering the shared mental models within an organisation is often not easy (Altman *et al.*, 1998; Argyris *et al.*, 1978; Romme *et al.*, 1999; Romme *et al.*, 1997; Senge, 1990) because it demands "inquisitiveness, openness and a willingness by managers to challenge assumptions and tackle conventional wisdom. Otherwise, behaviour will continue to be ruled by habit, and the status quo will remain undisturbed" (Garvin, 2000: 19). As such, organisational double-loop learning "violates a set of nested organisational norms" (Argyris *et al.*, 1978: 3) or what Peter Drucker (1994) refers to as "the theory of the business" and what this thesis calls "shared mental models".

Argyris and Schön (1978: 28) formulated one of the key research question in organisational learning: "How can organisations learn to become better at double-loop learning?". This research question has set scholars to work in finding ways of (1) enhancing individual double-loop learning since altering shared mental models of an organisation starts by altering its member's individual mental models, and (2) sharing these altered individual mental models throughout the organisation. To accomplish these goals the literature proposes many tools, such as simulation, role plays, and dialogue and discussion (Bennett *et al.*, 1995; Isaacs, 1993;

Romme *et al.*, 1997; Schein, 2003; Warren *et al.*, 1999). Although they are all admittedly of some value, this thesis focuses on the use of simulation models, specifically microworlds*,* in enhancing individual and organisational double-loop learning.

1.1.3 Conceptual framework

Figure 1.1 depicts the conceptual framework of this thesis. This framework translates the above-mentioned theory on individual and organisational learning into the world of fisheries management and illustrates where microworlds fit in. Additionally, it includes the broader environmental context in which organisations and their members work, as fisheries management is not made by one single organisation acting in complete isolation. However, this conceptual framework does not aim to include all relevant concepts to fisheries management, nor does it offer an exhaustive overview of current debates. It only represents challenging issues related to learning from microworlds in fisheries management.

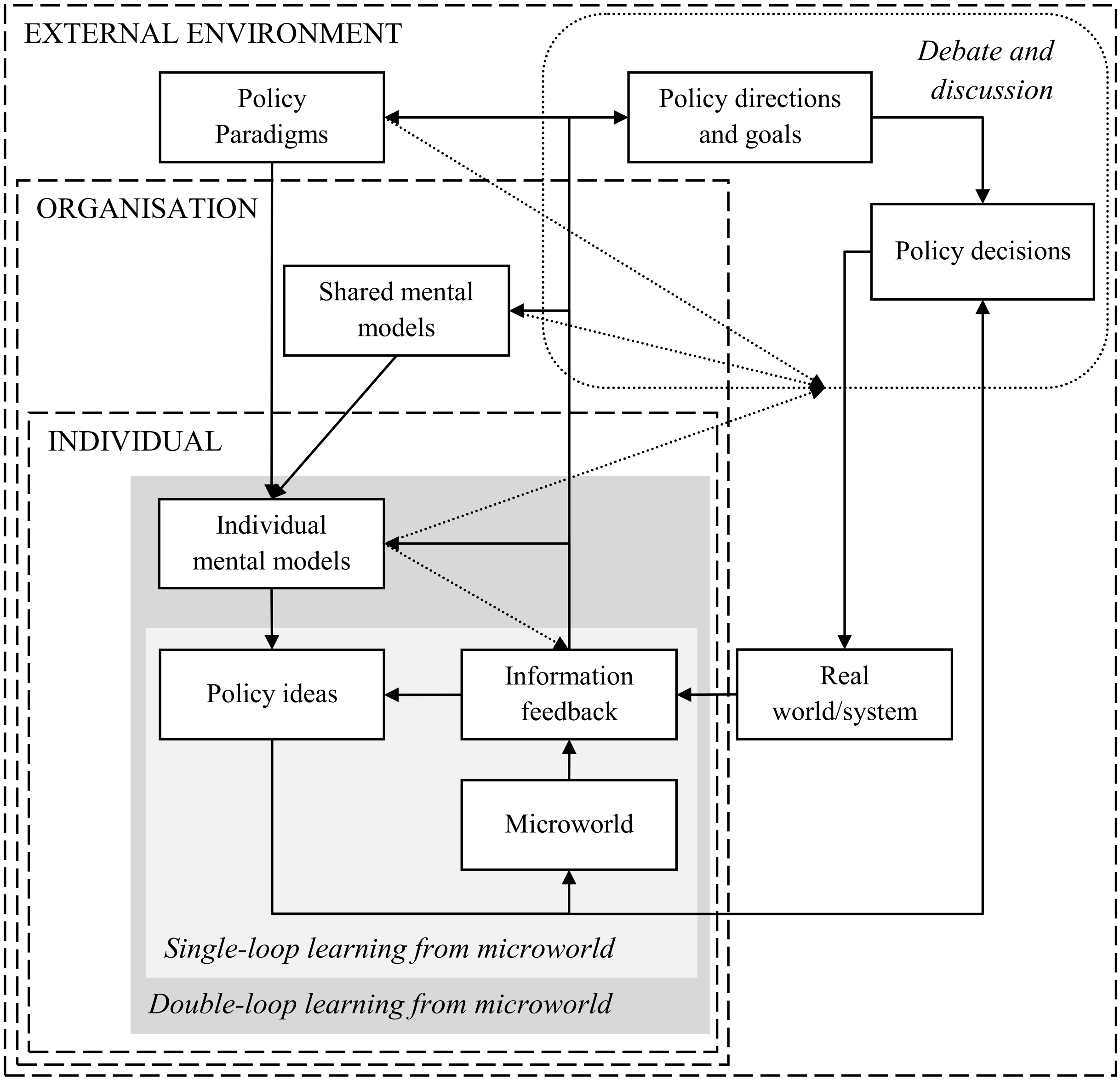
We conceptualise fisheries management as a policy development process that consists of single- and double-loop learning processes at both the individual and organisational level. At the heart of policy development is the process of discussing *policy ideas* amongst stakeholders (i.e., organisations) in an attempt to arrive at actual *policy decisions* that are in line with previously discussed *policy goals and directions*. These policy decisions are then implemented in the *real world/system,* leading to *information feedback*. In turn, this information feedback allows individuals to evaluate the implemented policy decisions based on their individual mental models about the desired state of the fisheries system. Eventually, this evaluation results in new or similar policy ideas that can be further tested throughout this individual single-loop learning process. In addition, information feedback from the real world can also result into individual double-loop learning when it not only alters policy ideas but also feeds back to alter the individual's mental models. If this happens, different policy ideas will emerge from the same information because this information is now processed and interpreted by these new mental models.

Next, since decision makers are members of organisations, these organisations' shared mental models influence the decision maker's individual single- and double-loop learning processes through affecting their individual mental models. Hence, individuals from different organisations may perceive the same information feedback from the real world differently, resulting in different policy ideas. In turn, individual double-loop learning processes may also influence the shared mental models of the organisation through debating and discussing (Morecroft, 1984) the information feedback from the real world in the light of the altered individual mental models of its members. When these debates and discussions are successful, the altered individual mental models become absorbed in the organisation's shared mental models. Additionally, changed individual- and shared mental models in combination with information feedback can also result in setting new policy directions or goals for future fisheries management through debate and discussion.

Finally, this conceptual framework must take *policy paradigms* into account. A policy paradigm is “a framework of ideas and standards that specifies not only the goals of policy and the kind of instruments that can be used to attain them, but also the very nature of the problems they are meant to be addressing. Like a Gestalt, this framework is embedded in the very terminology through which policymakers communicate about their work, and it is influential precisely because so much of it is taken for granted and unamenable to scrutiny as a whole” (Hall, 1993: 279). Hence, such policy paradigms, like organisational shared mental models, also influence individual mental models. If this happens, individuals will align their policy ideas with the policy paradigm they have encountered and will try to implement these policy ideas into the real system through bringing them into debate and discussion when setting policy decisions. If such policy ideas get implemented, information feedback from the real world can be used at the individual level to (1) refine policy ideas or (2) (further) revise mental models. Additionally, information about the real system can also feed back at the organisational level to alter the organisations’ shared mental models through debate and discussion. Finally, debate and discussion of this information feedback can also result in altered policy directions and goals and even (but probably more in the long run) in altering the policy paradigm itself; this is repeatedly referred to in the literature as a “paradigm shift” (Kuhn, 1962).

Up to now, this conceptual framework has dealt with what is referred to as “real world feedback” (Kunc *et al.*, 2006: 4) or “experimenting with reality” (De Geus, 1996: 32). However, real-world feedback of the kind outlined above cannot always be relied on to alter mental models or policy directions because information feedback from the real world is not available until implementation is well underway and therefore massively delayed. Hence, it is often already too late to alter policy directions or goals when real world information feeds back to the decision makers - possible damage to the system has often already been done. One way to overcome this learning deficiency is the use of simulation models or microworlds to test policy ideas. This enables the organisations to test the policy ideas for future impact before implementing them in the real world. This modelling capability introduces a new feedback path to the conceptual framework with identically the same feedback processes towards (1) individual policy ideas, (2) individual mental models, (3) shared mental models, (4) policy directions and goals, and (5) policy paradigms as in the real world feedback processes. However, the main difference is that the rehearsal capability of microworlds introduces fast-acting “virtual feedback” (Kunc *et al.*, 2006), which policymakers can use to adjust policy ideas in order to anticipate and avoid meaningless policy discussions or, at worst, implementation of inferior policies in the real world. At the heart of this thesis are these virtual feedback learning processes, specifically the individual single- and double loop learning that occurs from using microworlds (both types of learning are indicated with a grey square in the conceptual framework).

Figure 1.1: The conceptual framework



(Source: Own compilation, composed of Kim, 1993b; Kunc *et al.*, 2006; Morecroft, 1984; Sterman, 2000)

1.2 Research questions

This thesis investigates to what extent learning takes place from microworlds. Many of the "virtual feedback"-links in the conceptual framework (Figure 1.1) lack conclusive proof because there is little well-structured evaluation research. These links thus present "axiomatic beliefs" about learning processes from microworlds and have given rise to the key research questions of this dissertation. This thesis also represents ILVO's first steps toward developing microworlds that could play a central role in formulating a long-term strategy for the Belgian fisheries system. The first two research questions serve to gain insights into the Belgian fisheries system itself (i.e., the real world) before simulating it. The third research question is about playing in our microworld, which reveals the long-term effects policy instruments have on the Belgian fisheries system. The last research question evaluates whether stakeholders in the Belgian fisheries system learn from our microworld through a strictly controlled experimental design.

The first two research questions, about gaining insight into the Belgian fisheries system map the various competitive strategies present in the Belgian fishing industry.

1. ***Do firms in the Belgian fishing industry cluster around a limited array of competitive strategies (i.e., strategic groups) that result in performance differences?***

Fiegenbaum *et al.* (1988: 21) state that "identifying the strategic dimensions that define strategic groups is a key issue in understanding how competitors formulate their strategies" and that "strategic groups help us understand which firms compete strongly with each other". Consequently, knowing these strategic differences between firms within the same industry is crucial when managing fisheries and implementing public policies (Oster, 1982: 376). Hence, identifying these strategic groups is essential for developing a long-term strategy for the Belgian fisheries system. Moreover, it will also help in developing the microworld since a decision will need to be made about how to include the fishing fleet in the microworld. Does it need to be included as a homogenous fleet consisting of homogenous agents, or do intra-industry groupings (i.e., strategic groups) exist that must be taken into account in the microworld?
See Chapter 2 below.

2. ***Do firms in the Belgian fishing industry stick to their competitive strategy in the long-term?***

In line with the first research question, it is also valuable to investigate if the firms stick to their competitive strategy over the long run since this would allow us to omit "firm-movement" (Fiegenbaum *et al.*, 1993: 75) between groups in the microworld. This would drastically simplify the microworld.
See Chapter 2 below.

The next research question examines the long-term effects that policy instruments have on the Belgian fisheries system, as revealed by policymakers' play in the microworld.

3. ***Do policymakers have the policy instruments at hand to align the real fisheries world with the desired world of their individual mental models?***

Single-loop learning in fisheries management is the learning process in which policymakers compare information about the state of the real fisheries system to various goals, perceive discrepancies between desired and actual states, and take actions in the form of policies, that (they believe) will cause the real world to move towards the desired state. However, the

question remains to what extent do policymakers in Belgian fisheries have the policy instruments at hand to take such corrective actions.
See Chapter 4 below.

The last question evaluates whether stakeholders in the Belgian fisheries system learn from the microworld, using a strictly controlled experimental design.

4. ***Do stakeholders learn (differently) from playing with microworlds?***

This research question focuses on the individual single- and double loop virtual feedback learning processes from microworlds. It tests whether these virtual feedback learning processes actually exist or if they are only the creation of flimsily-based elaborate theorising.
See Chapter 5 below.

1.3 Research contributions

The point of writing a doctoral thesis is, on the one hand, to conduct research that contributes knowledge to a scientific discipline, and on the other hand, to apply that knowledge to the practice of a profession (Schneberger *et al.*, 2009; Van De Ven, 1989). The following questions thus arise: do the answers to this set of research questions contribute to science? Are these research questions and answers relevant to the practice of our profession?

1.3.1 Scientific contribution

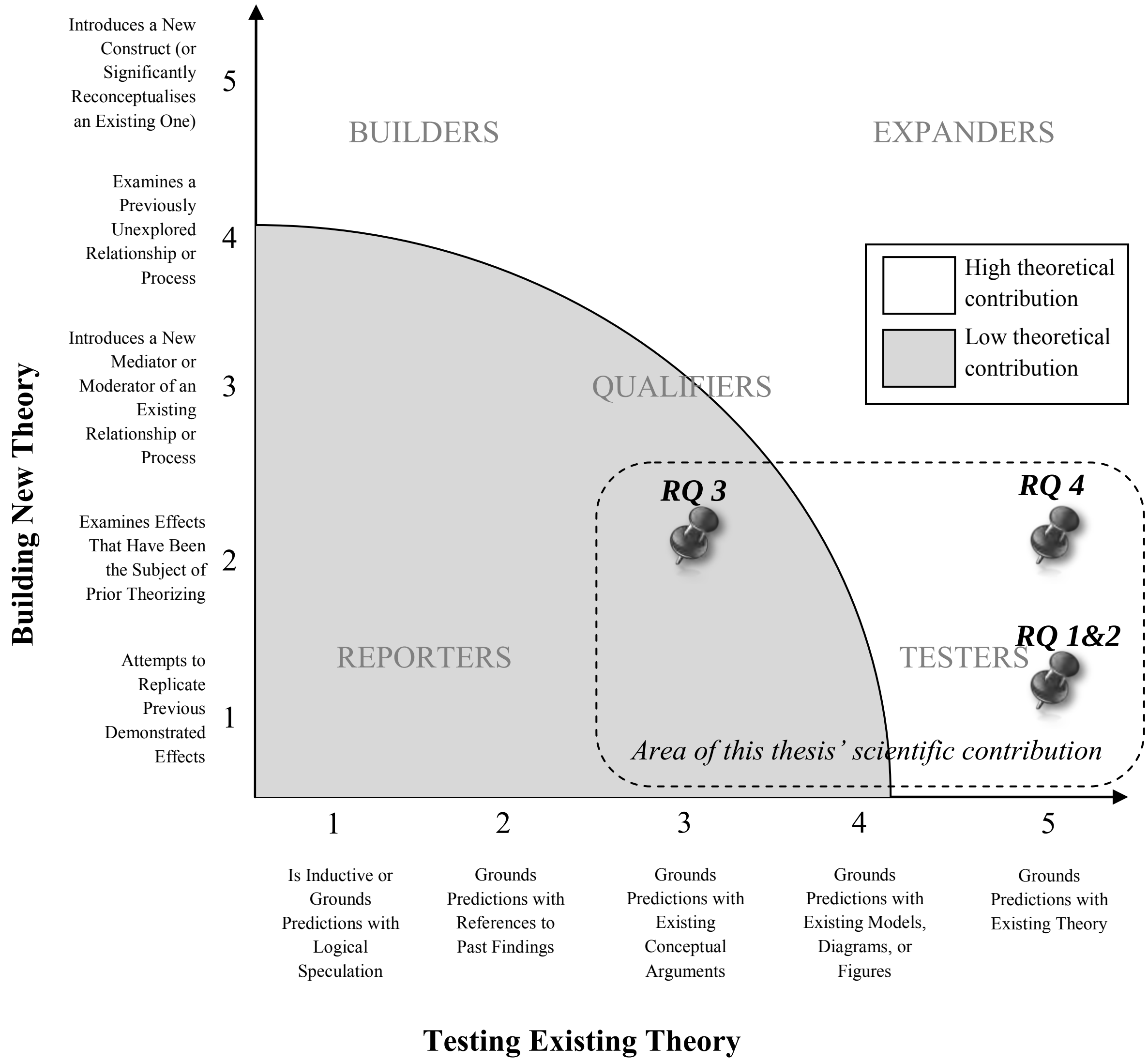
Contributing to the advances of science equals contributing to theory (Whetten, 1989). However, not everyone agrees on what constitutes a theoretical contribution (e.g., Colquitt *et al.*, 2007; Whetten, 1989). Colquitt and Zapata-Phelan (2007) state that theoretical contributions are generally characterised as theory building or theory testing (or both). Hence, they combine these two types of contributions to create a two dimensional space in which the contribution of each empirical study can be mapped. They also identify five important areas in this space resulting in a taxonomy that can be used to categorise and "label" an empirical study's theoretical contribution as: (1) reporters, (2) testers, (3) qualifiers, (4) builders, and (5) expanders. This thesis uses both this space and taxonomy to visualise where the theoretical contribution of each of our research questions is situated (Figure 1.2). Since this thesis is in applied economics it is not surprising that most research questions aim to test existing theory instead of build theory. Therefore, the contribution of this thesis can be situated in the bottom right hand corner of Colquitt and Zapata-Phelan's (2007) scientific contribution space.

To be more specific, the first two research questions aim to test if strategic group theory also holds true in the case of the Belgian fishing industry. Since strategic group theory is a "true theory" (Sutton *et al.*, 1995) or what Schneberger *et al.* (2009: 54) would refer to as a "big T theory", addressing research questions 1 and 2 need to be situated on the horizontal axis at the level of “grounding predictions with existing theory”. On the vertical axis, they need to be situated at the lowest level of theory building, since they attempt only to replicate previously demonstrated effects, now within the Belgian fishing industry. These research questions will result in empirical research which can be classified as a “tester”. They investigate the generalisation of strategic group theory to a new industry. Therefore, they also investigate if the temporal and contextual factors (i.e., the “who”, “where” and “when” of a theory (Whetten, 1989)) that set the boundaries for the generalisation of a theory can be expanded. This is an important scientific contribution because generalisation is a core characteristic of any “big T theory”. Additionally, in addressing these research questions, this thesis also applies and tests the rigid methodological approach of Ketchen and Shook (1996) in identifying clusters in strategic management research.

The research on the third research question is more of a “qualifier” as it contains moderate levels of both theory testing and theory building. Its aim is only to illustrate whether policymakers have the policy instruments at hand to align the real fisheries world with the desired world of their individual mental model. This question examines effects that have been previously theorised about in fisheries management science. This research is not conclusive in nature. Its purpose is exploratory as it grounds its predictions mainly on existing conceptual arguments. Nevertheless, its real scientific value lies in further introducing microworlds in fisheries management science – a tool that allows policymakers to visualise and rehearse fisheries policy strategies grounded in fisheries management theory.

Last, the fourth research question tests to what extent different stakeholders learn from playing with microworlds. It tests the axiomatic belief of individual and organisational learning theory that decision makers do learn from using microworlds. Consequently, it grounds predications in existing theory and examines important effects that have been the subject of prior theorising. This study will be a „tester’ but goes beyond simply replicating previous well-demonstrated effects. Hence, it contributes more to theory when compared to the research necessary to address the first two research questions. This research verifies if the connections between the concepts related to individual single- and double-loop learning from microworlds are correct. As such, it tests what Whetten (1989) refers to as the “how” of the theory. This is vital to future justification of using microworlds in learning processes.

Figure 1.2: Scientific contribution of this thesis ("RQ" = "Research Question")



(Source: Own compilation, adapted from Colquitt *et al.*, 2007)

1.3.2 Practical relevance

This thesis is also relevant to the work of policymakers and practitioners, particularly in the fields of fisheries and fisheries management.

The study on strategic groups in Belgian fisheries has practical relevance for both policymakers and ship owners. Introducing strategic group theory to fisheries management could simplify the current Common Fisheries Policy of the European Union. Policymakers can use strategic group theory to simplify both fisheries management and regulation, as strategic group theory shows "which firms compete strongly with each other" (Fiegenbaum *et al.*, 1988: 21). The knowledge of these strategic differences between firms is crucial to both managing fisheries and implementing public policies (Oster, 1982: 376). As a result, strategic groups can form the basis for developing regulation instead of using either (1) tremendously detailed typologies of sub fleets solely based on technical characteristics (i.e., fishing methods, gear modifications and mesh sizes) (EC, 2002) or (2) overly specified classification systems based on métiers (EC, 2008) which probably need simplification (i.e., aggregation of métiers into fleet segments) if they want to be workable in practice. Moreover, this strategic group approach would result in a more strategic form of regulation. This means that the regulation would emphasise (1) affecting strategic groups' competitive advantages and (2) managing rivalry between strategic groups. In addition, this would also limit the range of policy instruments needed to regulate fisheries. Ship owners can use the results on the performance of these strategic groups to determine if they are still satisfied with their current strategic direction, and if so, they can compare their performance to the average performance of their group peers. It shows them the different performance potentials for the different competitive strategies in the current industry. This then allows them to reflect on current business and change strategic course if desired, based on performance indicators.

The second aspect of this thesis is a microworld in which stakeholders of the Belgian fisheries system can "play" and gain long-term insight into the effect that policy instruments would have on the Belgian fisheries system. Consequently, this microworld is a learning laboratory for ex ante evaluation of possible policy strategies (De Geus, 1997; Keys *et al.*, 1996) since it offers a risk free environment in which policy strategies can be evaluated much faster than in the real world (De Geus, 1997; Sterman, 2000). In addition, it can also be used as a transitional object in which strategies are rehearsed and visualised (Morecroft, 1999) bringing them into debate and discussion (Morecroft, 1984) among stakeholder groups. This can lead to a better mutual understanding among the stakeholder groups of the fisheries management problems resulting in changing (1) knowledge, (2) attitudes, and (3) behaviour toward policy instruments and management systems as a whole. Additionally, developing and running this microworld can also introduce the value of simulation to practitioners within the Belgian fisheries system.

1.4 Research design and structure of the thesis

1.4.1 Research design

The proposed research questions will be investigated through the research design represented in Figure 1.3. It presents an overview of the different steps in the research, their exploratory or conclusive objectives and the way they are linked with data sources and methods. A more detailed description of the different methodologies is described in the relevant chapters in addition to further analysis and the presentation of the results.

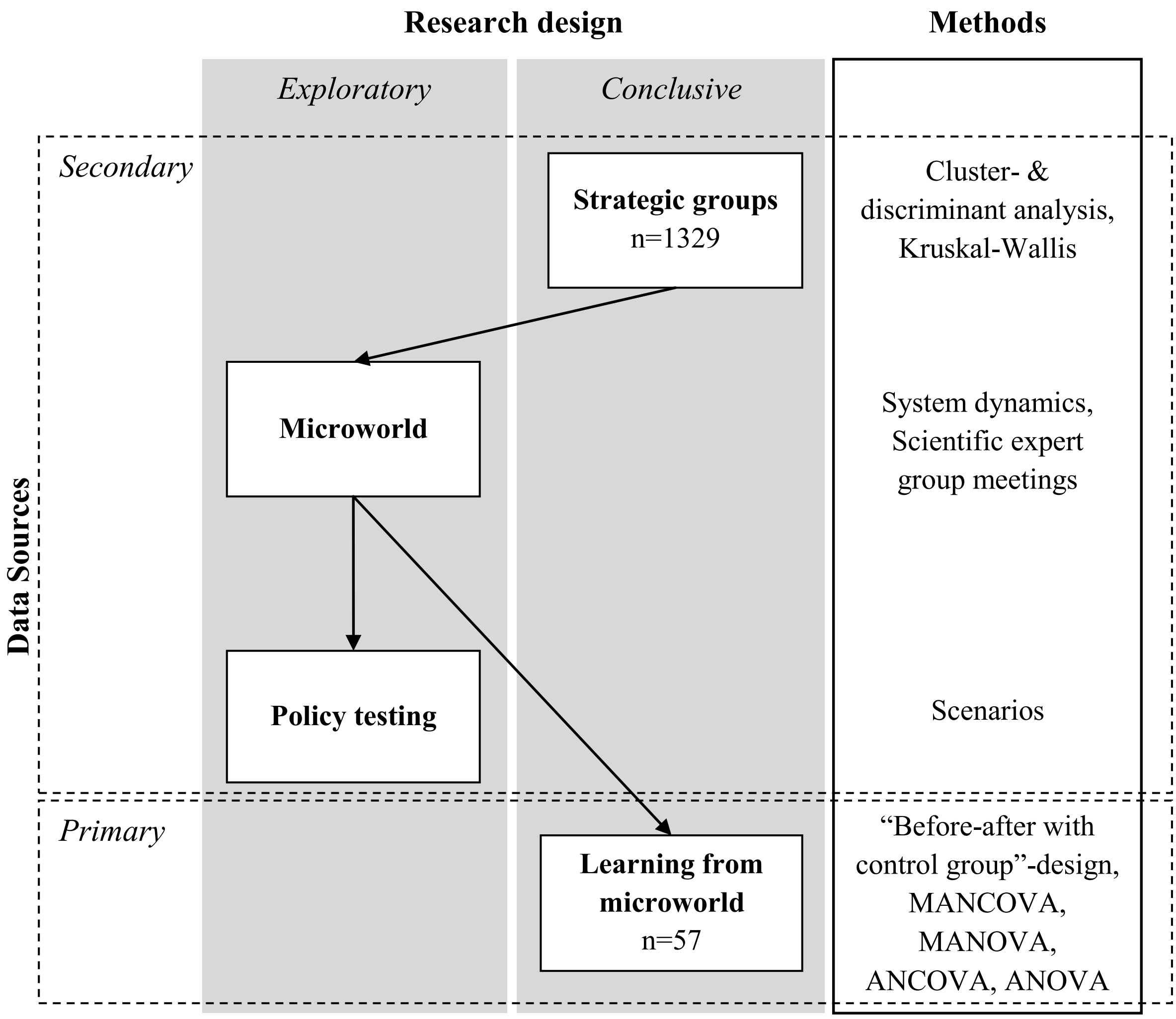
The first step of this thesis is to examine the first two research questions related to strategic groups in the Belgian fishing fleet using secondary data in conclusive research. This data was collected between 1997 and 2006 and is found in two databases: (1) “Belsamp”, a database hosted at the Section Fisheries Biology of ILVO-Fisheries, and (2) the database of the Belgian Sea Fishery Service of the Flemish government hosting accounting data. However, since most accounting data in the Belgian fisheries industry is currently still collected through surveys that are taken on a voluntary basis, sample sizes average only 50% of the total fleet. Additional data is collected at the fishing firms where necessary, which results in sufficiently large samples. The methodology used to determine valid strategic groups in the Belgian fishing industry is a combination of cluster- and discriminant analysis. Finally, non-parametrical statistical tests are performed to determine performance differences between these groupings and the second research question on firm movements among these groupings is addressed based on comparing simple counts and percentages.

The second step of this thesis is to develop a microworld about the Belgian fisheries system and the effect policy instruments have on it. The link between the previous study and this microworld is that the study helped us gain insight into the organisation of the fishing industry and use it to develop the microworld. The applied modelling methodology is system dynamics. The insights and information needed to develop the microworld were based on scientific expert group meetings of fisheries scientists from ILVO. These insights and information were then verified, where possible, through literature and simple data analyses. Finally, informal contacts with the fishing industry and policymakers made our conceptualisation of the fisheries system more accurate. To run this microworld, secondary data was collected between 1997 and 2006, mainly from the same two databases as the previous study, i.e., (1) “Belsamp” and (2) the database of the Belgian Sea Fishery Service of the Flemish government. We collected additional data from (1) official legislation documents and (2) yearly reports on the state of Belgian fisheries published by the Belgian Sea Fishery Service of the Flemish government.

After having developed the microworld, the third step was to run the microworld and research if policymakers have the policy instruments at hand to align the real fisheries system with the desired one embedded in their individual mental model. The method used is running multiple scenarios through the microworld in an attempt to meet four predefined objective functions (or social welfare functions) in fisheries management. The latter serve the purpose of reflecting the different individual mental models policymakers can have about the desired state of the fisheries system. Hence, the nature of this study is explorative and based on secondary data.

This thesis ends by formulating an answer to the research questions related to learning from microworlds. For this, an experiment was performed involving three stakeholder groups at both the national and European level of the Belgian fisheries system. They were (1) policymakers, (2) scientists and (3) ship owners and skippers. A total of 57 participants played with our microworld within the context of a “before-after with control group”-experiment. This experimental design illustrates the causal effect a microworld has on individual learning processes. The research design is conclusive and is based on primary data collected through the questionnaires administered both pre- and post-test. The analysis also applies different forms of analysis of variances.

Figure 1.3: Research design, data source and methods



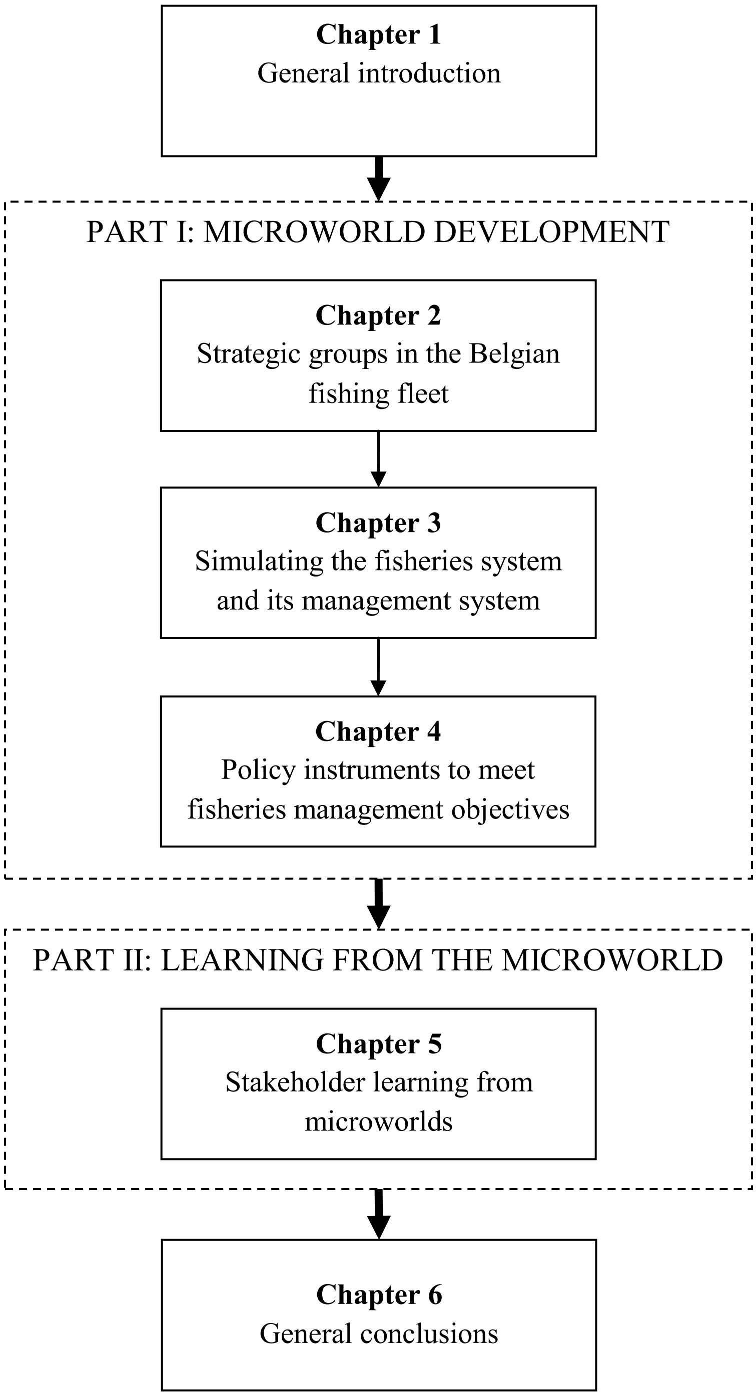
(Source: Own compilation)

1.4.2 Structure of the thesis

This dissertation consists of six chapters structured into two parts. Figure 1.4 provides a visual overview of how these six chapters are interrelated.

The introductory chapter presents the research problems, questions, framework and design of the thesis. Part I (Chapters 2, 3 and 4) presents the framework in which the microworld was developed and tested. Chapter 2 illustrates the organisation of the fishing industry. It borrows the concept of strategic groups, together with its theory from the field of strategic management, and applies it to the case of the Belgian fishing fleet. This chapter investigates if strategic groups in the Belgian fishing fleet can be defined based on their differences in competitive strategies. Additionally, it also looks at performance differences, firm movement and group loyalty between these groupings. Chapter 3 then presents the microworld about the Belgian fisheries system. This microworld (1) serves as a tool to learn about fisheries management and (2) investigates if stakeholders learn from microworlds. The link between this third chapter and the second is that the second helps to gain insights in the organisation of the fishing industry that can now be used in the process of developing the microworld. Finally, Chapter 4 then looks at fisheries management using the microworld developed in Chapter 3 and investigates whether policymakers have the policy instruments at hand to align the real fisheries system with the desired one embedded in their individual mental model. Part II (Chapter 5) investigates whether stakeholders learn (differently) from the microworld. This was based on experimental results where three stakeholder groups from both the national and European level of the Belgian fisheries system participated: (1) policymakers, (2) scientists and (3) ship owners and skippers. Chapter 6 concludes with a discussion of the main results, research limitations, implications of our findings and directions for future research.

Figure 1.4: Structure of the thesis

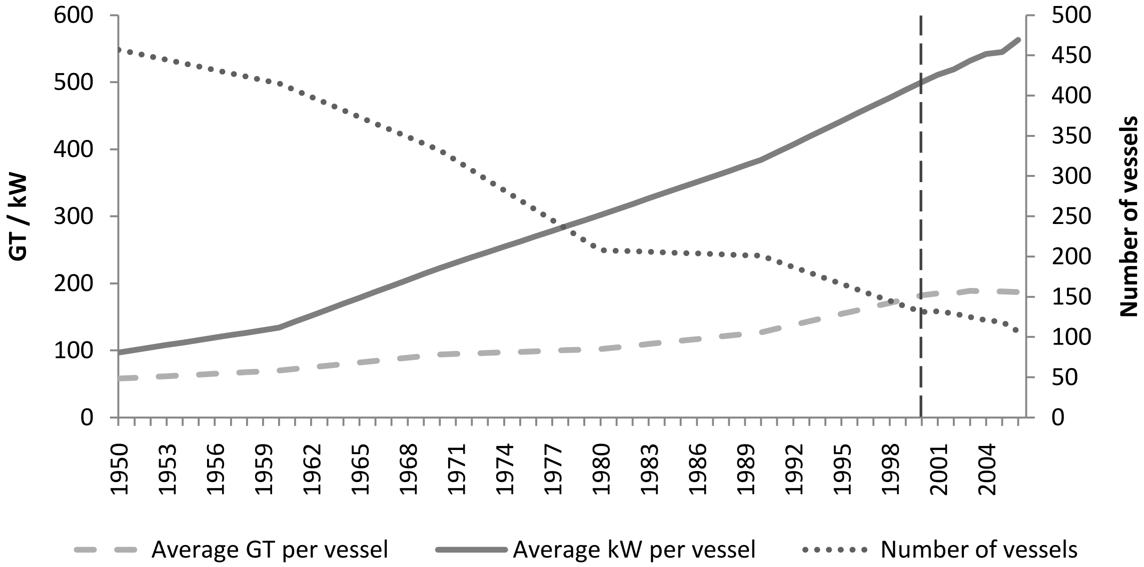


(Source: Own compilation)

1.5 Belgian fisheries: a brief overview of the empirical setting

The Belgian fleet is currently the smallest fleet active in the Northeast Atlantic region of the European Union, with 107 vessels in 2006 (Tessens *et al.*, 2006a). The Northeast Atlantic region is heavily fished, with roughly 60000 fishing vessels landing about 4.5 million tonnes of fish and employing almost 200000 fishermen (Polet *et al.*, 2006). Because the Belgian fleet is small, its gross added value to the gross domestic product of Belgium is 0.04%, or 1.9% to the total value of agro- and horticulture (Anon., 2007). Nevertheless, since Belgium has a very small coast line, this industry is important at the regional level of the coastal area because it directly employs 900 persons at approximately 100 family-run shipping companies. Further, indirect employment in the fish processing industry is estimated at 1329 people and 5000 people in fisheries related side industries (Anon., 2007). This industry also has an impact on the regional socio-economic structure: specific trades correlated with fisheries, distribution chains, fish processing companies, fish traders, catering industry and coastal tourism (Van den Eynde *et al.*, 2009). However, future prospects are not good for the Belgian fisheries industry. The current crisis is bankrupting many shipping companies (Polet *et al.*, 2006; Polet *et al.*, 2007; Stouten *et al.*, 2007c; Van den Eynde *et al.*, 2009). Fleet size has declined dramatically between 1950 and 2007; from 457 to 107 vessels, respectively (Figure 1.5). One might expect that such dramatic decline in fleet size to be accompanied by a similar major decline in total fleet capacity in terms of gross tonnage and engine power. However, both gross tonnage and engine power have remained quite stable. The reason for this is that the average gross tonnage (GT) and engine power (kW) per vessel have multiplied over these years resulting in a small but powerful fleet; where in 1950 an average vessel only had 58 GT and 97 kW, one in 2006 had 187 GT and 563 kW.

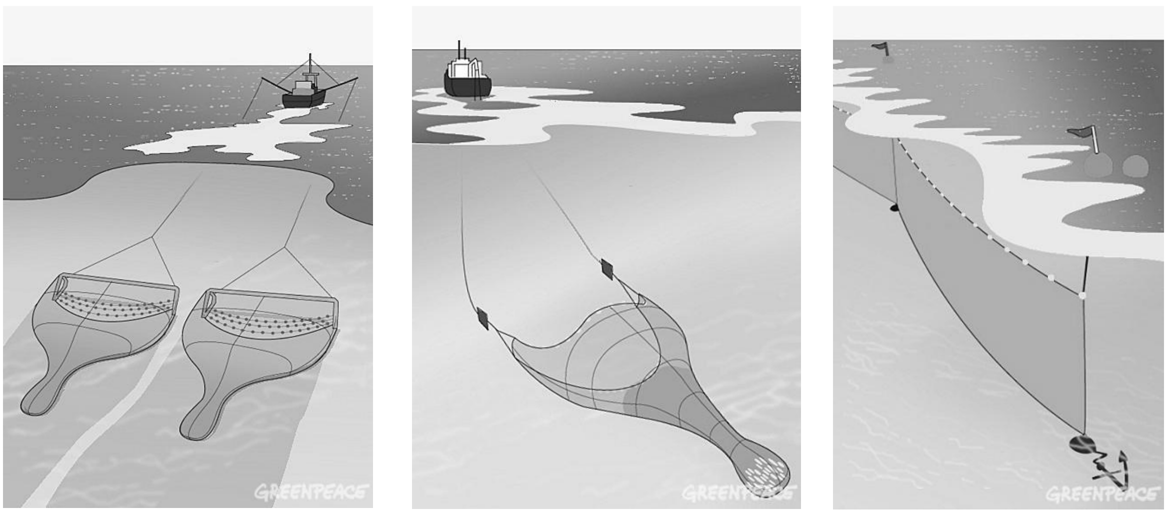
Figure 1.5: Key figures of the Belgian fishing fleet, 1950-2006 ("GT" = "Gross Tonnage"; "kW" = "Vessel power in kW"; the vertical dashed line separates 10 year linear interpolated data from yearly data)



(Source: Own compilation, adapted from Tessens *et al.*, 2006a)

The main fishing method in Belgian fisheries is beam trawling, practised by almost 95% of the fleet. Beam trawling is an active fishing method in which nets are towed over the sea-bed (Figure 1.6). A horizontal beam keeps the net open (Gabriel *et al.*, 2005; Van Craeynest, 2008). Beam trawling is a highly mixed fishery and contains a number of problems such as high fuel and material consumption (Depestele *et al.*, 2006; Polet *et al.*, 2007; Stouten *et al.*, 2007c; Van Craeynest, 2008), heavy seafloor impact (Anon., 2005; Hilborn, 2007b; Lindeboom *et al.*, 1998; Polet *et al.*, 2006; Polet *et al.*, 2007) and low species- and size-selectivity (Fonteyne *et al.*, 2002; Lindeboom *et al.*, 1998). The other 5% of the fishing is done using otter trawling and passive fishing methods like trammel and gill netting (Van Craeynest, 2008). Otter trawling is also an active fishing method but differs from beam trawling since the horizontal spread of the net is now ensured through the hydrodynamic force exerted to the otter doors (Figure 1.6) (Gabriel *et al.*, 2005). Hence, its main advantage compared to beam trawling is reduced water resistance and less contact with the sea-bed resulting in reduced fuel costs and ecological damage (Van Craeynest, 2008; Vanderperren, 2008). Finally, passive fishing methods is a collective name grouping the fishing methods where "the fish comes voluntarily to the gear" (Gabriel *et al.*, 2005: 5). The main advantages of passive fishing is excellent fuel efficiency and low sea-bed impact (Depestele *et al.*, 2008; Verhaeghe *et al.*, 2008). These fishing methods are only marginally used in Belgium, but of them, trammel nets are most common. Trammel netting anchor nets at sea in an upright position, allowing fish to swim into it. In trammel nets, fish get entangled in the poorly visible netting (Figure 1.6) (Depestele *et al.*, 2008; Gabriel *et al.*, 2005; Verhaeghe *et al.*, 2008).

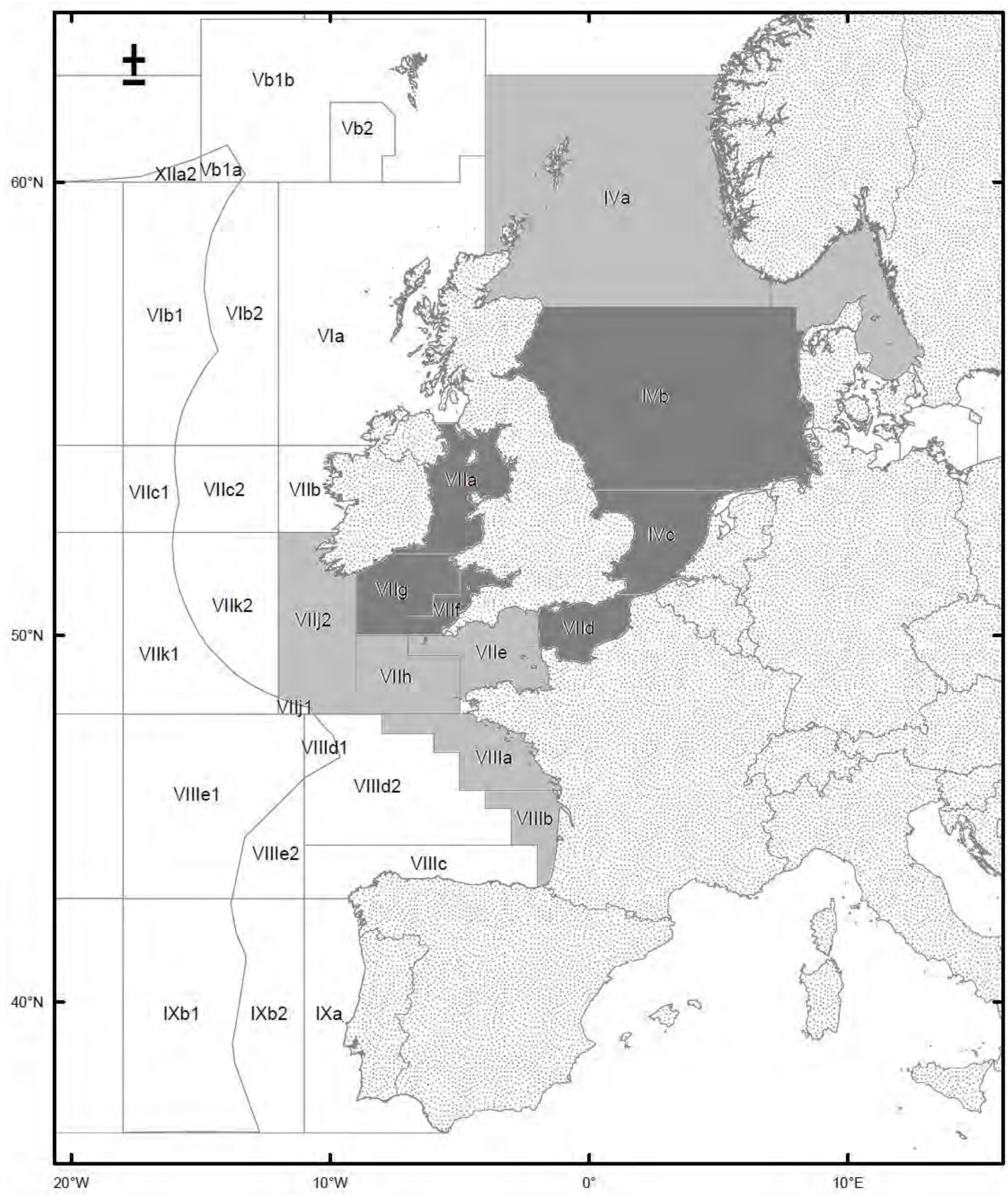
Figure 1.6: Main fishing methods in Belgium, from left to right: (1) beam trawling, (2) otter trawling and (3) trammel netting



(Source: www.greenpeace.org)

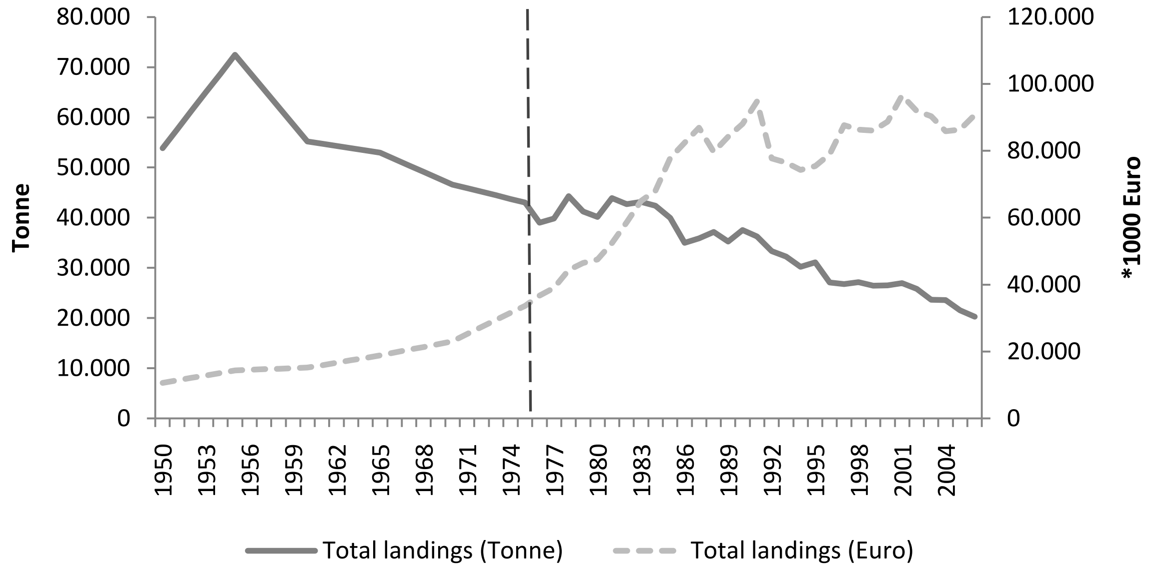
The Belgian fleet is active in several ICES-areas (Figure 1.7), the most important of which are (1) Central North Sea (IVb), (2) Southern North Sea (IVc), (3) Irish Sea (VIIa), (4) Eastern Channel (VIId), (5) Bristol Channel (VIIf) and (6) South East Ireland (VIIg). The less important fishing grounds are (1) Skagerrak (IIIa), (2) Northern North Sea (IVa), (3) West Scotland (Via), (4) Western Channel (VIIe), (5) South East of Ireland (only VIIh and VIIj) and (6) the Gulf of Gascogne (only VIIIa). In 2006, the fleet landed 20264 tonne fish from these fishing grounds worth over 90M euro. Ninety percent of these landings were sold in Belgian auctions and supplied Belgian consumers with approximately 12% of their demand for wild fish (Anon., 2007). When looking at the evolution of these landings over the last decades, it is clear that the Belgian fleet's total landings declined from roughly 54000 in 1950 to 20000 tonnes in 2006 (Figure 1.8). However, when expressed in monetary value, the total landed value of fish increased significantly over these decades. This is mainly due to the almost exponential growth in average fish prices.

Figure 1.7: Fishing grounds were the Belgian fishing fleet is active ("Dark grey" = "Important fishing ground" and "Light grey" = "Less important fishing ground")



(Source: Own compilation, based on ICES areas)

Figure 1.8: Total landings of the Belgian fishing fleet (in tonne and current €), 1950-2006 (the vertical dashed line separates 5 year linear interpolated data from yearly data)



(Source: Own compilation, adapted from Tessens *et al.*, 2006a)

As most Belgian vessels are beam trawlers, the total landings consist mainly of a mixture of demersal species. The top ten landed species in 2006 indicate that plaice (4885 tonne) and Dover sole (3818 tonne) are the most important species in landed weight, followed by ray (1777 tonne), cod (1326 tonne) and lemon sole (883 tonne) (Tessens *et al.*, 2006a). Hence, plaice and Dover sole account for almost 50% of Belgian total landings. However, when looking at the landed value of these species, the rank order significantly changes. Dover sole is now by far the most important species, good for more than half the Belgian total landed value or 45M euro. Dover sole is followed far behind by plaice (9.74M euro), turbot (4.30M euro), lemon sole (4.18M euro) and anglerfish (4.15M euro). This clearly indicates a double overspecialisation in the Belgian fishing fleet: fishing method and target species. This makes the fleet vulnerable to sudden changes in the fishing environment, such as changes in fish consumption patterns, rising fuel prices and new policy directions, amongst others (Stouten *et al.*, 2007b; Van den Eynde *et al.*, 2009).

This vulnerability of the double overspecialised Belgian fishing fleet to changes in the fishing environment brings us to a discussion of the Belgian's fisheries management system as it aims to regulate this fisheries environment. The Belgian fisheries management system is largely based on the European Union's Common Fisheries Policy (CFP) (EC, 2002), given that Belgium is a member state of the EU. Hence, these European regulations are adapted to the Belgian setting and complemented further by national rules (in the form of ministerial decisions). The CFP mainly contains biologically and economically restrictive policy instruments. The most important of these are: (1) Total Allowable Catches (TAC); often referred to as the "cornerstone of the CFP" (Karagiannakos, 1996), (2) maximum fishing days and (3) licences (Stouten *et al.*, 2008). However, and despite evidence that they may exacerbate rather than reduce problems in fisheries (Mesnil, 2008; Sumaila *et al.*, 2007), public aid in the form of subsidies is also an important feature of the CFP. The Belgian fisheries management system contains seven important policy instruments, being: (1) total quota based on the TACs, (2) the allocation of these total quota over sub fleets, (3) maximum fishing days, (4) catch restrictions per fishing day, (5) licences, (6) decommissioning fees, and (7) investment subsidies.

When looking at the evolution of these policy instruments over time between 1986 and 2006, it is clear that the number of species under quota restrictions has increased from 11 to 24 species. Despite more than doubling the number of species under quota restrictions, the total quota has declined significantly: from approximately 39000 to 29000 tonnes (approximately 25% less). Additionally, the number of days fishermen were allowed to fish also declined from 285 to 260 days (a decline of around 10%). During this period, Belgium had also applied licencing and held several decommissioning rounds (e.g. 2004-2006) with increasing decommissioning fees per vessel in an attempt to reduce overcapacity by buying out unprofitable vessels and destroying their licences. Finally, during these two decades investment subsidies have also been widely granted to modernise older vessels and/or to experiment with other fishing methods.

PART I: MICROWORLD DEVELOPMENT

Photo: The fishing port of Ostend
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Chapter 2: Strategic groups in the Belgian fishing fleet

2.1 Introduction

The field of strategic management research aims to explain the differences in performance of firms (Gonzalez-Fidalgo *et al.*, 2002; Rumelt *et al.*, 1994; Short *et al.*, 2007). As a result, the determinants of performance have long been of central interest to strategic management researchers. Their research has emphasised determinants at four primary levels of analysis: (1) firm; (2) strategic group; (3) industry; and (4) nation (Gonzalez-Fidalgo *et al.*, 2002; Porter, 1998; Short *et al.*, 2007). Research at the firm level focuses on how key within-organisation features shape outcomes. Perhaps the most popular perspective guiding this work is the resource-based view of the firm, which argues that a firm's bundle of resources and capabilities drive its performance (e.g., Barney, 1991, 1997; Wernerfelt, 1984, 1995). Strategic groups researchers argue that firms cluster around a limited array of competitive strategies that result in performance differences (e.g., Cool *et al.*, 1987; Fiegenbaum *et al.*, 1990b; Hunt, 1972; Porter, 1979). Research at the industry or nation level examines the extent to which the industries (e.g., Bain, 1972; Mason, 1939; Rumelt, 1991) or the nations (Porter, 1998) where firms compete shape their performance. Although research has illustrated that each of these levels of analysis can explain a significant number of performance differences between firms (Gonzalez-Fidalgo *et al.*, 2002; Porter, 1998; Short *et al.*, 2007), this study examines the heterogeneity of the Belgian fishing fleet based on strategic group theory.

Strategic group theory defines strategic groups as "clusters of firms within an industry that have common specific assets and thus follow common strategies in setting key decision variables" (Oster, 1990: 61). Strategic group theory adopts mostly "a post-strategy position, offering a taxonomy of strategies employed by firms, where individual firms are classified into strategic groups through comparison of past strategic investments" (Leask *et al.*, 2005: 458). As a result, strategic groups are an analytical tool to examine differences in firm performance primarily based on a firm's "realised strategy" (Mintzberg, 1978). Only a few studies have defined strategic groups based on a firm's "intended strategy" (e.g., Dess *et al.*, 1984; Fombrun *et al.*, 1987). Hence, strategic groups are "groupings" (Hatten *et al.*, 1987) instead of "groups" since they are used as an analytical tool to define intra-industry taxonomies.

In defining strategic groups, firms within an industry are clustered based on the homogeneity of their "past strategic investments". These past strategic investments are primarily embodied in the state of the firm's "resource configuration" (Fiegenbaum *et al.*, 1988: 8) because these strategic investments are a collection of past competitive strategic decisions that attempted to make sure that a firm's resource configurations could not readily be "imitated by firms outside the group without substantial costs, significant elapsed time, or uncertainty about the outcome of those decisions" (McGee *et al.*, 1986: 150). Hence, the essence of group membership is that the state of resource configurations represent "mobility barriers" (Caves *et al.*, 1977) which deter or inhibit the movement of a firm from one strategic group to another. As a result, Hatten *et al.* (1987) define a high mobility barrier as a competitive advantage on strategic group level, while low mobility barriers may be competitive disadvantages. Therefore, the defining characteristics of strategic groups arise from the source of their mobility barriers, i.e., a firm's resource configuration.

A distinct stream within empirical research has supported the notion of strategic groups. Central to these various studies have been one or more of the following research questions: (1) do strategic groups exist within industries; (2) does the existence of strategic groups affect overall industry performance; (3) does performance differ among strategic groups; and (4) do strategic group structures change over time? Viewed collectively, research has answered the first two questions positively (Cool *et al.*, 1988; Hatten *et al.*, 1977; Hatten *et al.*, 1978; Hawes *et al.*, 1984; Newman, 1978). However, research on the third question has produced conflicting evidence (Barney *et al.*, 1990; Cool *et al.*, 1988; Ketchen *et al.*, 1997; Thomas *et al.*, 1988). Linkages between strategic group and firm performance have been identified in the following industries: brewing (Hatten *et al.*, 1977; Hatten *et al.*, 1978), chemical processing (Newman, 1973, 1978), consumer goods (Porter, 1973), paints and allied products (Dess *et al.*, 1984), industrial products (Hambrick, 1983), U.S. insurance (Fiegenbaum *et al.*, 1990b), and retail mail-order (Parnell *et al.*, 1993), among others. However, these linkages were often equivocal since some studies only used one performance indicator (e.g., Hatten *et al.*, 1978) and others have used multiple indicators but fail to find rigorous linkages between strategic groups and all of these performance indicators (e.g., Cool *et al.*, 1987; Fiegenbaum *et al.*, 1990b; Katobe *et al.*, 1993). Finally, research addressing the last research question mainly proved that strategic groups are "stable" over time (Cool *et al.*, 1987; Fiegenbaum *et al.*, 1990b; Oster, 1982).

The objectives of this study are in line with these central questions in strategic group research. The objectives are: (1) to define strategic groups within the Belgian fishing fleet; (2) to examine the performance differences among these strategic groups; (3) to examine if firms (i.e., vessels) move between strategic groups over time; and (4) to examine if firm-movement (i.e., vessel-movement) differs across strategic groups. These objectives are then translated into the following four null hypotheses:

> $H0_1$: All vessels belong to the same strategic group.
> $H0_2$: All strategic groups perform the same.
> $H0_3$: Vessels do not move among strategic groups over time.
> $H0_4$: Each strategic group encounters equal firm movement.

Testing these hypotheses begins with a brief description of already existing taxonomies and classifications in Belgain fisheries, illustrating their shortcomings and why they differ from the strategic group concept. Next, the methodology is described to define strategic groups within the Belgian fishing fleet. Central to this methodology is the use of a two-stage clustering procedure. In addition, the methods used to enhance the external- and criterion-related validity of the cluster solutions are explained. The section ends with a discussion on the statistic tests used to examine the performance differences across the strategic groups and the methods used to measure changes in group membership. Section 2 presents the results, starting with a determination of the key resources of vessels of the Belgian fishing fleet. It then defines five strategic groups within the Belgian fishing fleet, each having distinct strategies related to the earlier defined key resources of vessels of the Belgian fishing fleet. Last, the results about the performance differences and firm-movement across these strategic groups are given. Section 3 discusses the results in the light of strategic group research. It also discusses the limitations of the study and highlights the value of strategic groups in improving fisheries management. Section 4 presents the conclusions.

2.2 Materials and methods

2.2.1 Existing taxonomies and classifications

Although the Belgian fishing fleet may seem homogenous at first glance, important distinctions between fishing methods and sub fleets are made using different taxonomies or classifications that serve as frameworks for data collection, regulation or reporting. Following the FAO's (1999) technical paper on "Definition and classification of fishing gear categories", the Belgian fleet can be subdivided by fishing method. This classification of fishing methods is a commonly accepted and comprehensive classification of all fishing methods around the world. Next, the Belgian fleet can also be divided into sub fleets corresponding to European legislation (EC, 2002). EU regulation aggregates vessels in fleet segments mainly based on technological characteristics (i.e., fishing methods, gear characteristics and mesh size). The EU also reports yearly economic performance indicators per sub fleet. In these reports (e.g., EC, 2003, 2004), three sub fleets are identified: (1) beam trawlers over 24 metres, (2) beam trawlers under 24 metres, and (3) shrimp beam trawlers. Belgian policymakers also use a sub fleet classification in reporting yearly key figures of the state of Belgian fisheries over the last decade (e.g., Tessens *et al.*, 2004a, 2005a, 2006a). They distinguish (1) coastal fishers, (2) eurocutters, (3) large beam trawlers, (4) other small fleet segment, and (5) other large fleet segment. Finally, at the European level, there is now the emergence of a new approach to fleet classification in fisheries. Instead of classifying vessels in fleet segments, they now start to classify fishing trips in métiers. These métiers should "reflect the fishing intention, e.g. the species targeted, the area visited, and the gear used, at the start of a fishing trip" (Marchal, 2008: 674). Following this métier approach, a vessel can now be assigned to more then one class (i.e., métier) during a certain time frame. However, each of these classifications has one or more problems, for instance: (1) the classification is overly complex; (2) the classification only uses one type of "clustering variable"; (3) the classification contains more than one leftover category (i.e., "others"); (4) the classification is not exhaustive; or (5) the classification is based on intention which can differ significantly from actual behaviour. As a result, despite the validity of all of these taxonomies, they have not emerged from a strategic approach and thus do not satisfy the definition and conditions of strategic groups.

2.2.2 Defining strategic groups in the Belgian fishing fleet

Strategic groups' defining characteristics arise from the source of their mobility barriers. McGee and Thomas (1986) identify three sources of mobility barriers: (1) the state of market-related resources, (2) the state of production and logistics resources, and (3) the state of infrastructure and corporate resources. However, the literature has still not agreed on how to start actually choosing the most relevant or dominant resources within these sources of mobility barriers. As a result, a variety of methods have been used to derive groupings in empirical research settings, resulting in a non-uniform approach and choice of resources (Fiegenbaum *et al.*, 1988; Ketchen *et al.*, 1996; McGee *et al.*, 1986; Short *et al.*, 2007; Thomas *et al.*, 1988). Howard and Venkatraman (1988: 539) state that "some researchers specify the characteristics of the groups *a priori,* based on extant theoretical rationale, and subsequently employ data-analytic techniques to confirm or validate their theoretical groupings. In contrast, others derive the grouping structure *a posteriori* based on empirical results on a specific data set."

This study specifies the defining resources of the strategic groups *a priori* based on a triangulation of methods (Ketchen *et al.*, 1996). First, a "cognitive approach" (Ketchen *et al.*, 1996) is used to generate a first list of relevant resources. This is done through four in-depth interviews with fisheries scientists of the Institute for Agricultural and Fisheries Research (ILVO), where the interviews continued as long as they contributed new resources to the list. Next, theoretical rationale (i.e., a "deductive approach" (Ketchen *et al.*, 1996)) in combination with a meeting held with these fisheries scientists resulted in determining the key resources that are the source of the strategic groups' mobility barriers and therefore create the strategic groups' competitive advantages. As a result, these resources create the strategic dimensions (or axes) of the "strategic space" (Edgar *et al.*, 1994; Fiegenbaum *et al.*, 1990b; McGee *et al.*, 1990) in which vessels position themselves by means of the state of their resource configuration.

Having defined the main resources, they will serve as the cluster variables in the cluster analysis to cluster vessels with the same state in resource configurations. However, before clustering, the cluster variables are tested for multicollinearity among the variables through Pearson's r correlation coefficient and Haitovsky's χ^2_H (Haitovsky, 1969). In applying the clustering, the suggestions made by Ketchen et al. (1996) on the application of cluster analysis in strategic management research were taken into account. They believe that the key to surmounting the problems and critiques related to cluster analysis (i.e., cluster analysis' reliance on researcher judgement) is the vigorous pursuit of triangulation, both within-method and between-methods triangulation. As a result, this study starts with applying a two-stage clustering procedure where a hierarchical algorithm is used to define the number of strategic groups and cluster centroids. These results serve next as the starting point for subsequent non-hierarchical clustering (Hair *et al.*, 1998; Ketchen *et al.*, 1996). Research has shown that this two-stage procedure increases validity of solutions (Ketchen *et al.*, 1996; Milligan, 1980; Punj *et al.*, 1983). Afterwards, the obtained cluster solutions of the non-hierarchical clustering are tested for significant differences between the cluster means through Kruskal-Wallis tests and Mann-Whitney U post hoc tests both with Bonferroni adjustment (α'= 0.005 since k=5 where k equals the number of strategic groups). The outcome of these non-parametric tests will allow us to meet our first objective and hypothesis.

The hierarchical clustering uses Ward's method (Ward, 1963) in combination with Euclidean distance on the standardised individual vessel data (i.e., z-scores) for each cluster variable from 1997 till 2006 (i.e. one clustering across the entire period studied) where each year is a census. Ward's method is best suited for this study since (1) it is the method which focuses the most on homogeneity within groups by minimising their within-cluster sum of squares (Hair *et al.*, 1998), and (2) its main disadvantage, namely its sensitivity to outliers (Ketchen *et al.*, 1996), is eliminated since our dataset – a census – has no outliers. In addition, Ward's method was also commonly used in earlier studies clustering strategic groups (e.g., Fombrun *et al.*, 1987; Gonzalez-Fidalgo *et al.*, 2002). To determine the optimal number of clusters, the first largest percentage change in the agglomeration coefficient will be used (Hair *et al.*, 1998). The rationale behind this "stopping rule" is to preserve the "tightness" (Fiegenbaum *et al.*, 1990b; Harrigan, 1985) of the clusters as the algorithm progressively combines groups. Validation of the outcome of this rule occurs through visual inspection of the dendrogram and *a priori* theoretical rationale (i.e., the existing taxonomies of the Belgian fishing fleet). The non-hierarchical clustering is a k-means clustering based on the cluster results of the hierarchical clustering. It is again, as the hierarchical clustering, one clustering across the entire period studied.

Further, this study needs to validate the obtained cluster solutions. Ketchen et al., (1996: 447) state "the goals of validation are to ensure that a cluster solution has external validity (i.e., is representative of the general population of interest) and criterion-related validity (i.e., is useful for the prediction of important outcomes)". To prove the external validity of the cluster results, this study only needs to focus its effort on proving the reliability of the cluster solution (a necessary condition of validity) because the dataset is a census of the general population of interest. The reliability of the cluster solution is proven through triangulation. For the hierarchical clustering, the within-method triangulation consists of applying multiple clustering algorithms to confirm the results given by Ward's method. In addition, this study also used multiple methods to determine the optimal number of clusters within the use of Ward's method. For the non-hierarchical clustering, the within-method triangulation consists of running the k-means clustering multiple times with random clustering centroids instead of those given by the hierarchical clustering. In addition, the k-means clustering results were also compared with its non-parametric equivalent (i.e., k-mediods) which partitions around the mediods instead of the means. Finally, discriminant analysis is used to determine how well the vessels were classified into the right strategic groups, since the aim of this technique is to predict the membership of an individual (the vessel) to a qualitative group defined beforehand (strategic groups) (Rason *et al.*, 2007). This is a form of between-method triangulation. For this, discriminant analysis bases its "judgment" on the discriminant functions that discriminate most between these groups.

Criterion-related validity can be accessed through significance tests on external variables which are theoretically related to the cluster but not used in defining the clusters (Ketchen *et al.*, 1996). Given our second hypothesis ("all strategic groups perform the same"), performance indicators are the obvious choice for external variables. Since performance consists of many "dimensions", this study will look at (1) operational and (2) financial measures, and (3) measures of overall effectiveness (Venkatraman *et al.*, 1986). The operational dimension of performance is measured through (1) the average landings of a vessel (kg mixed fish), and (2) the average landings of a vessel per fishing hour (kg mixed fish/fishing hour). Here, financial performance measures (all expressed in nominal values) are mostly based on the average gross operating profit of a vessel, starting with its absolute value (i.e., GOP) followed by two relative measures: (1) the average gross operating profit of a vessel per fishing hour (GOP/fishing hour), and (2) the average gross operating profit of a vessel per kilogram of mixed fish landed (GOP/kg fish). Additionally, the absolute values of net operating profit are also given to illustrate the effect of the capital costs on the firm's financial performance. Finally, the measure of overall effectiveness is the average rate of return on investment, which indicates the profitability of the investment in relation to other alternative investments (Tietze *et al.*, 2005). It is calculated by dividing the yearly net operating profit of a vessel (in nominal value) by its estimated capital investment. Significant differences among strategic groups on these performance measurements are tested through Kruskal-Wallis tests (Cool *et al.*, 1988) in combination with Mann-Whitney U tests as post-hoc test both with Bonferroni adjustment ($\alpha' = 0.005$ since $k=5$ where k equals the number of strategic groups). Consequently, the outcome of these tests will formulate an answer to the second hypothesis of this study.

In order to test the third and fourth hypothesis on firm movement (vessel movement) across strategic groups, this study defines firm movement as "cluster analytic assignment of a firm to a different group than it had been in during the prior year" (Mascarenhas, 1989: 346). Consequently, in order to calculate firm movement rates between strategic groups, the yearly membership of each vessel was noted. Then, the number of vessels moving from one strategic group to another and the number of vessels remaining in the same strategic group in adjacent years are recorded. As a result, the firm movement rates are based on simple counts and percentages.

2.2.3 Data

Data on individual vessel characteristics and accounting data come from two databases. This study uses "Belsamp", a database hosted at the Section Fisheries Biology of ILVO-Fisheries, which contains detailed data on individual vessel characteristics. Financial data on individual vessel level came from the Belgian Sea Fishery Service of the Flemish government. They collect accounting data for the Belgian sea fisheries fleet through annual surveys. These surveys are taken on a voluntary basis and they sample on average 50 percent of the fleet (i.e., approximately 60 vessels) between 1997 and 2006. However, not all strategic groups are sufficiently present each year. Additional data was collected through the annual accounts of fishing firms, resulting in sufficiently high sample sizes for each strategic group per year. Finally, data related to investments and depreciation periods were confirmed by previous studies (e.g., Thøgersen *et al.*, 2009; Tietze *et al.*, 2005; Van Craeynest, 2008).

2.3 Results

2.3.1 The key resources of the Belgian fishing fleet

The outcome of the in-depth interviews with fisheries scientists at ILVO was a list of eight resources which were perceived as the sources of mobility barriers between strategic groups in the Belgian fishing fleet. These resources were thus seen as contributing to the competitive advantage of vessels, and are: (1) technology, (2) product range, (3) geographic reach, (4) fishermen's skill, (5) modernity level, (6) product quality, (7) markets, and (8) crew. "Technology" captures the difference in fishing methods a vessel uses to catch fish. Although the dominant fishing method in the Belgian fleet is beam trawling, they also use otter trawling and trammel netting. Technology is perceived as a very important discriminator between vessels since it reflects a fishermen's choice between active fishing (i.e., beam trawling and otter trawling) and passive fishing (i.e., trammel netting). The distinction between active and passive fishing methods is currently very important given the high fuel prices. "Product range" in fisheries is defined in this study as the landing compositions. It captures the difference between mixed fisheries and specialisation towards catching target species. "Geographic reach" captures how far offshore a vessel can go fishing. This is mainly determined by technical characteristics like engine power, tonnage and vessel length. "Fishermen's skill" captures the fishermen's knowledge of this "métier" and the fishing environment. "Modernity level" describes the state of the vessel: new versus old. "Product quality" captures the state of the landed fish, which is mainly a function of its treatment on board and the time between being caught and sold. "Markets" stands for the number of auctions a vessel uses to sell its fish. Finally, "crew" is the number of persons on board a vessel when fishing.

During a meeting in which the four previously interviewed fisheries scientists gathered, a choice was made about which of these eight resources were the dominant sources of high mobility barriers between strategic groups in the Belgian fishing fleet. This choice was guided by (1) their combined knowledge about the Belgian fishing fleet, (2) lessons learned from the existing taxonomies in Belgian fisheries, (3) the measurability of the resources, (4) data availability through past monitoring of the resources, (5) the literature on strategic groups (e.g., McGee, 1985; McGee *et al.*, 1990; McGee *et al.*, 1986; Thomas *et al.*, 1988); and (6) more specifically, the three sources of mobility barriers defined by McGee and Thomas (1986). Based on discussion, the decision was made to pick for each of the three sources of mobility barriers defined by McGee and Thomas (1986) the dominant one. A first step in this process was taken by looking at the measurability and the data availability of the eight resources. Table 2.1 illustrates the operational definitions and unit of measurement of these resources. "Fishermen's skill" is left out of the table because (1) it is an intangible and very complex resource to measure, and more importantly (2) it has hardly been monitored over the years. "Crew" is also left out because the number of crew members per vessel are nearly impossible to collect: they are not stored electronically and many media (often very volatile) have been used to inform authorities about the number of persons on board (e.g., fax, phone, e-mail and mobile phone text message). In addition, the average number of crew members per vessel is strictly regulated and is a function of (1) geographic reach, (2) vessel length, and (3) trip duration (KB, 1973: art 94) which are resources that are or (1) already taken into account (e.g., geographic reach and trip duration in the form of "product quality") or (2) highly correlated with one or more of the resources that are already taken into account (e.g., Pearson's r between vessel length and geographic reach (measured in engine power, kW) equals 0.92). Table 2.1 also illustrates that "Technology" is measured by two operational definitions reflecting the different dimensions of "Technology" (i.e. opposite choices). A second step was to decide source-by-source what the dominant resource is for each of the three theorized sources of mobility barriers by McGee and Thomas (1986). "Technology" was chosen as the dominant production resource since the fishing method a vessel operates was perceived as the most significant part of the production process. Additionally, it has also an effect on "Product quality" because the quality of the landed fish is also a function of the used method to catch the fish next to other processing variables like its treatment on board and the time between being caught, iced and sold. "Product range" was chosen as the dominant market-related resource since it captures the important strategic decisions and skills on targeting species. It is the result of being able to (1) target the species you want to catch (related to market conditions), and (2) choose which species to land and which to discard (related to market and regulatory conditions). Hence, it was perceived by the fisheries scientists that this resource of "product range" is therefore more important than the resource "Markets". Especially given the fact that Belgian fishermen do not land on many different markets (i.e., 89% of the fish caught by Belgian vessels in 2006 was landed in the three Belgian fish auctions). Finally, "Geographic reach" was chosen as the dominant infrastructure-related resource instead of the resource "Modernity level". The underlying reason is that the geographic reach of a vessel is very important within the Belgian context where different quota are allocate to different fishing ground. Additionally, modernity level is also a resource which differentiates more between vessels of the same strategic group instead of across strategic groups. In sum, this meeting concluded that the competitive advantage of sub fleets mainly lies within the configuration of the following three resources: (1) technology, (2) product range, and (3) geographic reach. These are: the dominant production resource, the dominant market-related resource and the dominant infrastructure-related resource, respectively.

Table 2.1: Operational definitions and unit of measurement of the resources perceived by fisheries scientists as being the sources of mobility barriers between strategic groups in the Belgian fishing fleet

Resources	Operational definition	Unit of measurement
Technology	1) Percentage of hours beam trawling (the dominant active fishing method in Belgian fisheries) in total number of fishing hours per year	Percentage (%)
	2) Percentage of hours trammel netting (the dominant passive fishing method in Belgian fisheries) in total number of fishing hours per year	Percentage (%)
Product range	Number of species landed per trip	# Species
Geographic reach	Engine power	kW
Modernisation level	The age of the vessel	Years
Product Quality	Trip duration in number of hours a vessel spent at sea per trip	# Hours
Markets	Number of auctions visited in a year	# Auctions

(Source: Own compilation)

2.3.2 The strategic groups of the Belgian fishing fleet

These three main resources serve as the cluster variables in a two-stage clustering procedure. However, before clustering, the cluster variables are tested for multicollinearity among them through Pearson's r correlation coefficient. Significant coefficients above the commonly agreed 0.80 illustrate severe multicollinearity between variables (Field, 2009). However, Table 2.2 indicates that this is not the case since there is only some correlation between product range and geographic reach (r=.68, p<.01). Additionally, Haitovsky's χ^2_H is highly significant (χ^2_H(6)=631.66, p<.01) which confirms that these cluster variables do not suffer severly from multicollinearity (Haitovsky, 1969).

Table 2.2: Testing the multicollinearity among the selected cluster variables (Pearson's r correlation coefficient), 1997-2006

		Technology		Product range	Geographic reach
		% beam trawling	% trammel netting	# Species/trip	kW
Technology	% beam trawling	1.00	-0.45**	0.19**	0.26**
	% trammel netting	-0.45**	1.00	-0.19**	-0.05
Product range	# Species/trip	0.19**	-0.19**	1.00	0.68**
Geographic reach	kW	0.26**	-0.05	0.68**	1.00

** Correlation is significant at the 0.01 level (2-tailed)

(Source: Own data)

Next, a hierarchical clustering (Ward's method – Euclidean distance) is performed to define the number of strategic groups and cluster centroids which will later be used as a starting point for subsequent non-hierarchical clustering. Determining the optimal number of clusters necessitates a trade-off between fewer clusters on the one hand versus less homogenous ones on the other. The most basic structure must be found that still achieves the necessary level of similarity within the clusters (Hair *et al.*, 1998: 476). To make this trade-off, the first large percentage change in the agglomeration coefficient in the hierarchical clustering is examined. Table 2.3 illustrates the percentage change in agglomeration coefficient for the ten final aggregations between clusters. This table clearly shows that the aggregation step between five and four clusters is accompanied by a first sudden jump in percent change in aggregation coefficient (approximately 31%). In addition, visual inspection of the dendrogram (Appendix 1) also confirms the choice of five clusters as a suitable number of clusters, although this method leaves more room for alternative interpretations (e.g., the use of only three clusters). Finally, the use of five clusters does not flatly oppose to *a priori* theoretical rationale since Belgian policymakers also use five sub fleets in reporting key figures of the Belgian fishing fleet. Consequently, the obtained cluster centroids for five clusters will serve as the initial cluster centroids for the subsequent non-hierarchical clustering (see Appendix 2 for the cluster centroids of the hierarchical clustering).

Table 2.3: Agglomeration coefficient for the hierarchical cluster analysis, 1997-2006

# clusters	Agglomeration Coefficient	% change in coefficient to next level
10	341.86	9.92
9	379.52	10.01
8	421.74	15.27
7	497.75	14.13
6	579.66	19.47
5	719.79	**30.93**
4	1042.12	40.99
3	1766.07	46.07
2	3275.04	38.35
1	5312	/

(Source: Own data)

Finally, although the hierarchical clustering was based on Ward's method, other clustering algorithms were also used to increase the reliability of the cluster solution (i.e., within-method triangulation). Although some cluster methods suggested quite different results (e.g., single linkage method), others came fairly close to the suggested outcome of Ward's method (e.g., average linkage and centroid method).

To determine the final cluster solution, a non-hierarchical clustering is performed with the cluster centroids of the hierarchical clustering as initial values. Table 2.4 presents the non-standardised cluster means and the number of cases per cluster. In addition, it also summarises which cluster means are significantly different from each other through a Kruskal-Wallis test and Mann-Whitney U post hoc tests, both with Bonferroni adjustment.

Based on these results, this study labels the first cluster as the large beam trawler fleet. These vessels have high-powered engines (on average, 855.32 kW), which allow them to cover all of the Belgian fishing grounds. They usually operate the beam trawl (i.e., an active fishing method) as their only fishing method (98.51% of their fishing time) and they land the highest variety of species (average 19 species). A second cluster is the fleet of small beam trawlers. They mainly differ from the large beam trawlers due to lower engine power (on average, 256.43 kW) and slightly less diverse landings (average 15 species). A third cluster is the shrimp beam trawler fleet. They differ from the small beam trawlers because their landing composition is quite specialised (average 5 species per trip; around 25% of the total landed weight is brown shrimp) and their engine is on average slightly less powerful (on average, 201 kW). However, since some small beam trawlers seasonally target shrimps and therefore temporarily behave as shrimp trawlers, the distinction between the small beam trawler fleet and the shrimp trawler fleet is slightly sensitive. A fourth cluster is the otter trawler fleet. They are similar to the small beam trawler fleet but differ in fishing method. Where the small beam trawlers use the beam trawl, otter trawlers use the otter trawl. However, both are active fishing methods. Additionally, otter trawlers also have a slightly less diverse product range (an average of 12.43 species per trip). Finally, a fleet exists that uses passive fishing methods (on average, 93% of the fishing time is spent on trammel netting). This sub fleet is labelled as the trammel netters. These vessels have engine powers of 319 kW on average, which is higher than most small beam trawlers, shrimp beam trawlers and otter trawlers, but lower than the large beam trawlers. They are specialised in just a few species (an average of 4 species per trip), comparable with the shrimp beam trawlers. However, further inquiry into the data unveils that these vessels do not target shrimp.

Table 2.4: Number of cases per cluster and the cluster means for the non-hierarchical k-means clustering (Mean), 1997-2006

	Cluster	1	2	3	4	5	Sig.
	Cluster labels	Large beam trawlers	Small beam trawlers	Shrimp beam trawlers	Otter trawlers	Trammel netters	
	N	573	265	379	86	26	
Technology	% beam trawling	98.51^{c}	93.20^{b}	92.15^{b}	8.99^{a}	4.10^{a}	.000
	% trammel netting	0.00^{a}	0.00^{a}	0.04^{a}	0.26^{a}	93.46^{b}	.000
Product range	# Species/trip	18.58^{d}	15.29^{c}	4.67^{a}	12.43^{b}	4.23^{a}	.000
Geographic reach	kW	855.32^{e}	256.43^{b}	200.72^{a}	300.67^{c}	380.96^{d}	.000

Different superscripts (a–b–c–d–e) indicate significantly different average means using Kruskal-Wallis and Mann-Whitney U as post hoc test both with Bonferroni adjustment (α'= 0.005 since k=5).

(Source: Own data)

To validate this final cluster solution, the within-method triangulation consists of running the k-means clustering multiple times with random clustering centroids instead of those given by the hierarchical clustering. These runs gave mostly the same or similar cluster results. In addition, the k-means clustering results were also compared with its non-parametric equivalent which partitions around the mediods instead of the means (k-mediods). The results of this clustering are given in Appendix 3 and confirm the obtained results of the k-means clustering, which increases its reliability.

Finally, discriminant analysis is used to determine how well the vessels were classified into the right strategic groups since the aim of this technique is to predict the membership of an individual (vessel) to a qualitative group defined beforehand (strategic groups) (Rason *et al.*, 2007)). Hence, this is a form of between-methods triangulation. For this, discriminant analysis bases its "judgment" on the discriminant functions that discriminate most between these groups. Table 2.5 compares the results of the cluster analysis with the discriminant analysis and illustrates how many of the cases (in percentages) are similarly classified in both analyses for each strategic group. With 99.2% of original grouped cases and 99% of cross-validated grouped cases correctly classified (see "b" and "c" under need the table in bold), this discriminant analysis forms an additional sound proof of the reliability of the cluster solutions gained by the k-means clustering.

Table 2.5: Cross table comparing the classification results of the k-means clustering with those of the discriminant analysis (%), 1997-2006

		Discriminant analysis				
		Small beam trawlers	Otter trawlers	Large beam trawlers	Trammel netters	Shrimp beam trawlers
Cluster analysis	Small beam trawlers	99.2	0	0	0	0.8
	Otter trawlers	0	98.8	1.2	0	0
	Large beam trawlers	1	0	99	0	0
	Trammel netters	0	0	0	100	0
	Shrimp beam trawlers	0.5	0	0	0	99.5
Cross-validated	Small beam trawlers	99.2	0	0	0	0.8
	Otter trawlers	0	97.7	1.2	0	1.2
	Large beam trawlers	1.2	0	98.8	0	0
	Trammel netters	0	0	0	100	0
	Shrimp beam trawlers	0,5	0	0	0	99.5

a Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b **99.2%** of original grouped cases correctly classified.

c **99.0%** of cross-validated grouped cases correctly classified.

(Source: Own data)

2.3.3 Performance among the strategic groups of the Belgian fishing fleet

Having defined five strategic groups in the Belgian fishing fleet, this study now examines whether the performance differs across these groups. Table 2.6 presents the averages of the different performance measures between the years 1997-2006 for each strategic group. In addition, it also summarises which averages are significantly different from each other through Kruskal-Wallis tests and Mann-Whitney U post hoc tests, all Bonferroni adjusted. As seen from the absolute values of landings and GOP, these results show that shrimp beam trawlers and trammel netters both have equally weak performance between 1997-2006. As a result, these two specialised fisheries have limited landings (mean yearly landings of 76244 and 44558 kilograms mixed fish, respectively), resulting in low absolute financial profit (55642 euro and 61469 euro on average, respectively). Otter trawlers and small beam trawlers have equally high GOPs and perform in absolute terms better than shrimp beam trawlers and trammel netters. They have average yearly landings of approximately 150 tonnes mixed fish and GOP of roughly 100000 euro. Both are roughly twice as high as shrimp beam trawlers and trammel netters. Finally, large beam trawlers have the highest GOP of all strategic groups, on average: twice as high as small beam trawlers and otter trawlers, and almost four times that of shrimp beam trawlers and trammel netters.

The relative landings per fishing hour approximate the same rank order, although the ratios between the strategic groups change. Shrimp beam trawlers land the lowest amount of mixed fish in a fishing hour (only 32.1 kg/fishing hour). Small beam trawlers, otter trawlers and trammel netters land slightly more (approximately 40 kg/fishing hour). Finally, large beam trawlers land the most fish per fishing hour namely (75.36 kg/fishing hour). In contrast, the relative measures of financial performance tell a different story in which trammel netters play an interesting role. Although trammel netters perform low in absolute values, their gross operating profit per fishing hour is as high as that of the large beam trawlers (around 50 euro per fishing hour), whereas their profit per landed kilogram mixed fish even outperforms every other strategic group (1.28 euro versus approximately 70 eurocent per kilogram mixed fish, respectively).

An examination of NOP and ROI does not reveal a clear pattern, which makes the significant differences between these strategic groups harder to interpret. However, it is certain that when taking the capital costs into account in the form of depreciations, shrimp beam trawlers are not profitable on average, as they have a negative NOP (-19358 euro). Hence, this also results into a negative ROI (-1.29%), meaning that they are unable to even earn back their initially invested capital. Small beam trawlers and otter trawlers perform little better with average NOPs of 9782 and 1850 euro, respectively. As such, they are barely profitable and therefore their ROIs are marginally positive. Finally, the large beam trawlers and trammel netters perform best, with ROIs of roughly 1.5 percent and average NOPs of 58243 and 11469 euro, respectively. Nevertheless, their performance is still poor, as ROI is only considered to be good from ten percent onwards (Tietze *et al.*, 2005: 3).

Table 2.6: Performance indicators among the strategic groups of the Belgian fishing fleet (Mean), 1997-2006

		Large beam trawler	Small beam trawler	Shrimp beam trawler	Otter trawler	Trammel netter	Sig.
Operational	Landings *(kg mixed fish)*	329717^{c}	143281^{b}	76244^{a}	158703^{b}	44559^{a}	.000
	Landings/fishing hour *(kg mixed fish/h)*	75.36^{c}	42.10^{b}	32.10^{a}	45.24^{b}	40.04^{b}	.000
Financial	GOP *(current €)*	218243^{c}	109782^{b}	55642^{a}	101850^{b}	61469^{a}	.000
	GOP/fishing hour *(current €/h)*	52.60^{d}	30.65^{b}	22.08^{a}	29.63^{a,b,c}	51.41^{c,d}	.000
	GOP/kg fish *(current €/kg mixed fish)*	0.69^{a}	0.74^{a}	0.67^{a}	0.66^{a}	1.28^{b}	.000
	NOP *(current €)*	58243^{c,d}	9782^{b}	-19358^{a}	1850^{a,b,d}	11469^{b,c}	.000
Overall effectiveness	ROI *(%)*	1.46^{c,d}	0.49^{b}	-1.29^{a}	0.09^{a,b,d}	1.53^{a,b,c}	.000

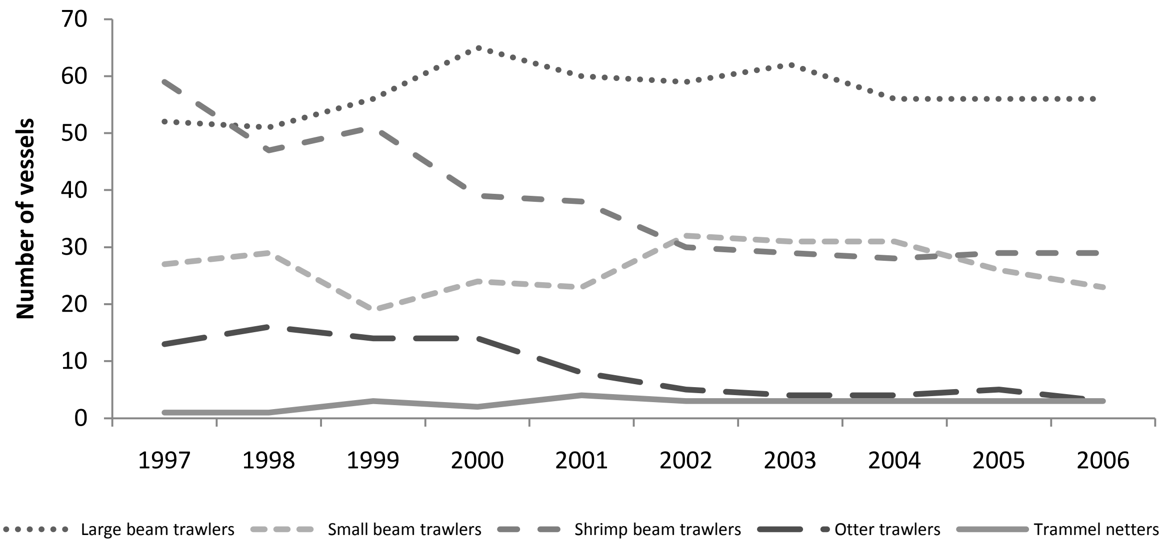
Different superscripts (a–b–c-d) indicate significantly different average means using Kruskal-Wallis and Mann-Whitney U as post hoc test both with Bonferroni adjustment (α'= 0.005 since k=5).

(Source: Own data)

2.3.4 Strategic group membership

Figure 2.1 illustrates the evolution of the size of the strategic groups between 1997-2006. It shows that large beam trawlers are the largest strategic group, except in 1997. From 1997 to 2000, the number of large beam trawlers increased from 52 to 65 vessels, an increase of 25%. After that time, it declined to 56 vessels in 2006 (a decrease of approximately 16%). The net change in fleet size between the years 1997-2006 is a slight net increase of four vessels or 7.1%. The small beam trawler fleet consisted of 27 vessels in 1997 and reached their maximum in 2002 with 32 vessels (+18.5%). However, during the subsequent years, this strategic group fell back to 23 vessels in 2006 (-39.1%). Consequently, there was a net loss of five vessels or 18.5% between the years 1997-2006. The strategic group of the shrimp beam trawlers has encountered a constant decline, except for 1999 where it gained four new group members compared to the previous year. This strategic group had 59 members in 1997 and declined to 29 in 2006 (-50.8%). The size of the otter trawler fleet declined the most. This strategic group had 13 vessels in 1997 but declined to three vessels in 2006 (-92.3%). The size of the trammel netter fleet increased from one vessel in 1997 to three in 2006.

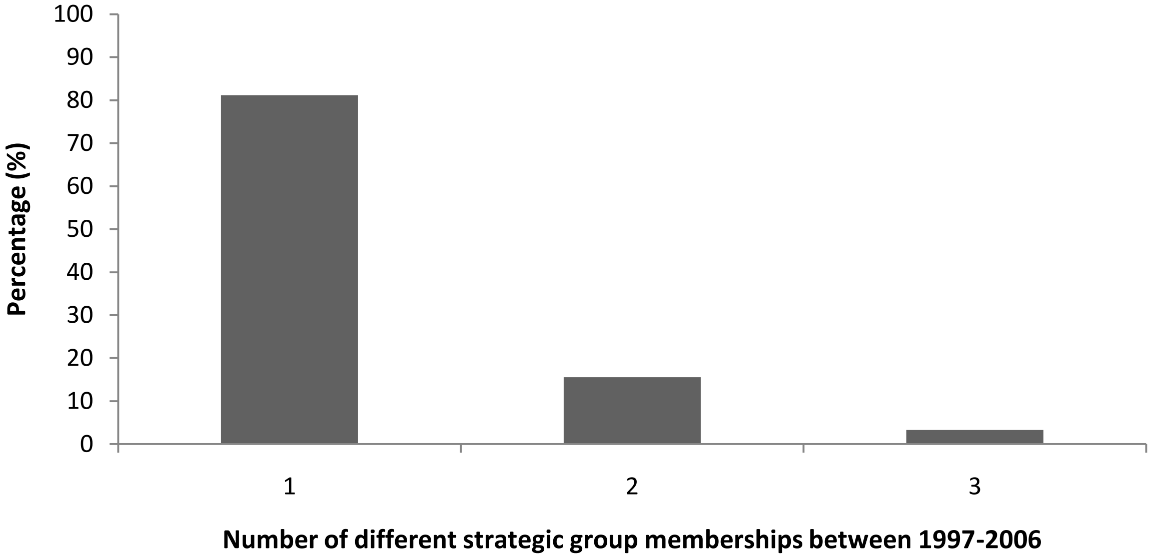
Figure 2.1: Size of the strategic groups (#vessels), 1997-2006



(Source: Own data)

These findings illustrate that the sizes of the strategic groups are not constant over time. In addition, it shows a recent trend of declining strategic group sizes, except for the strategic group of the trammel netters. Although the changes (especially the decline) in the size of strategic groups can be primarily explained by vessels exiting or entering the fishing industry (see infra, Table 2.7), they can also partly be explained by firm movements among strategic groups (i.e., shifts in group memberships or intra-industry shifts). However, Figure 2.2 illustrates that more than 80% of the vessels did not shift strategic groups between the years 1997-2006. It shows that once a vessel had decided on its strategic position in the fishing industry, it stayed in 80% of the cases in that position for a significant amount of time (in this case, 10 years). In addition, only 15.6% and 3.3% of the vessels shifted between two or three strategic groups, respectively. Consequently, vessel movement across strategic groups is not important in explaining changes in the size of strategic groups in the case of the Belgian fishing fleet. Strategic groups are therefore very stable over time in the Belgian fishing fleet.

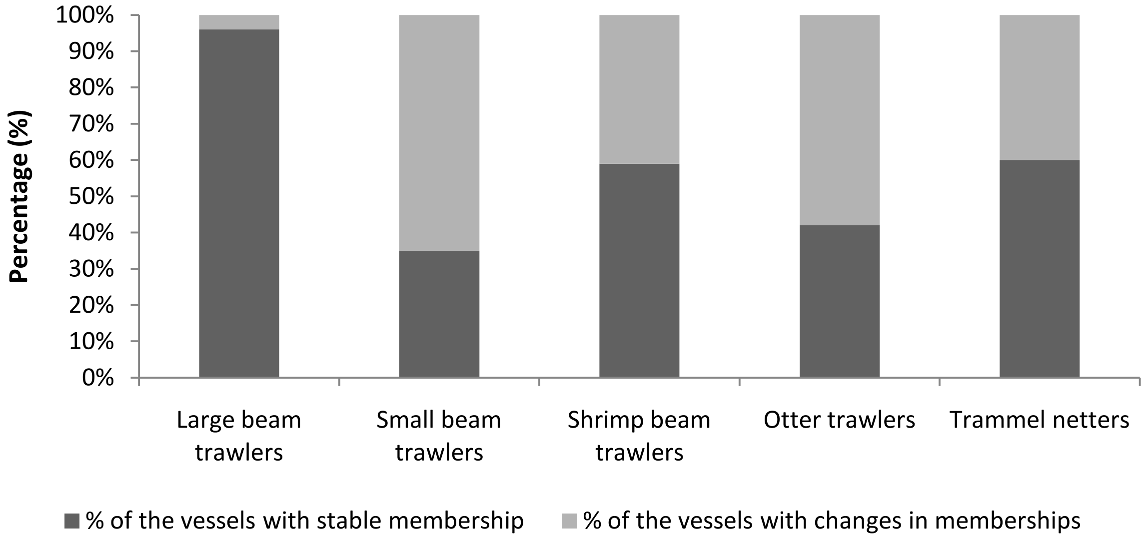
Figure 2.2: Vessels with one or more strategic group memberships (%), 1997-2006



(Source: Own data)

Figure 2.3 illustrates there are significant differences across the strategic groups when examining firm movement. The large beam trawler fleet is the strategic group whose group members shift the least of all strategic groups. Only 4% of all vessels who have been a large beam trawler during the years 1997-2006 have had other group memberships between 1997 and 2006. Small beam trawlers had most firm movement, as only 35% of these vessels have never been a member of other strategic groups. As a result, 65% of all small beam trawlers have been a member of other strategic groups. However, the strategic group of the shrimp beam trawlers has more stable memberships (approximately 60%) compared to the small beam trawlers. Like the small beam trawlers, the otter trawlers also show major fluctuations in group membership. Only 42% of the otter trawlers have never been a group member of other strategic groups during 1997-2006. Finally, 60% of the trammel netters have never shifted group membership between the years 1997-2006. As a result, this group, together with the shrimp beam trawlers, is the second most stable group in terms of group membership.

Figure 2.3: Differences in the stability of group memberships across the strategic groups (%), 1997-2006



(Source: Own data)

Finally, Table 2.7 illustrates the average yearly firm movement across strategic groups between pairs of adjacent years (i.e., 1997-1998, 1998-1999, …, 2005-2006). For the large beam trawler fleet, it is clear that they or (1) remain very loyal to their strategic group choice (on average, 92% of the cases), or (2) exit the fishing industry (on average, 8% of the cases). Consequently, there is no firm movement from large beam trawlers towards other strategic groups. When investigating firm movement from other strategic groups towards the large beam trawler fleet, one can observe that on average 91% of the total average firm movement towards large beam trawler fleet is from large beam trawlers from the previous year (so no actual firm movement), 8% is from outside the fishing industry, 1% is from small beam trawlers and 1% from otter trawlers. Small beam trawlers remain less loyal to their strategic choice (on average, 84% of the cases) when compared to the large beam trawler fleet (on average, 92% of the cases). They leave in on average 8% of the cases the fishing industry. In on average 1% and 7% of the cases they leave for the large beam trawler fleet or shrimp beam trawler fleet respectively. Firm movement towards the small beam trawler fleet is mainly from loyal small beam trawlers (86% of all cases). Shrimp beam trawlers and the otter trawlers move towards small beam trawlers in on average 7% and 5% of the cases respectively. Also interesting to notice is that on average only 2% of all firm movement towards the small beam trawler fleet is from new entrants to the fishing industry. Shrimp beam trawlers do in on average 80% of the cases not exit their strategic group. If they exit, they mainly opt to exit the fishing industry (on average, 9% of the cases) or move towards small beam trawlers (on average, 7%). However, there are also smaller migrations toward the otter trawler and trammel netter fleets (on average, 3% and 1% of the cases respectively). Firm movement towards the shrimp beam trawler fleet is on average for 88% accounted for by loyal shrimp beam trawler. The remaining movement towards this strategic group is made up by on average 5%, 3% and 4% from small beam trawlers, otter trawlers and new entrants from outside the fishing industry respectively. Next, otter trawlers are the least loyal among adjacent years of all five strategic groups since on average 75% of all firm movement is accounted to otter trawlers being loyal. Otter trawlers leave their strategic group, mainly and equally, through exiting the fishing industry or through movement towards the shrimp beam trawler fleet (both on average, 10% of the cases). However, they also move to a lower extent toward large and small beam trawlers (on average, 1% and 5% of the cases respectively). Firm movement toward otter trawlers is in on average 85% of the cases from loyal otter trawlers. In on average 10% and 3% of all cases it is from shrimp beam trawlers or new entrants from outside the fishing industry respectively. There is no observed firm movement towards otter trawlers from the other three strategic groups. Lastly, trammel netters are like large beam trawlers very loyal since in on average 91% of the cases they stick to their strategic direction between pairs of adjacent years. If they do not remain loyal, they leave in on average 4% of the cases the fishing industry or they leave for the shrimp beam trawler fleet. Vessels entering the trammel netter fleet are in both 8% of the cases from the shrimp beam trawler fleet or from outside the industry. 84% of the total average firm movement towards trammel netters is explained by loyal trammel netters.

Table 2.7: Yearly firm movement across strategic groups between adjacent years (#vessels, Mean), 1997-2006 (Cells containing no yearly firm movement are reported empty)

To / From	Large beam trawlers	Small beam trawlers	Shrimp beam trawler	Otter trawler	Trammel netter	Outside industry	**Total**
Large beam trawlers	52.89					4.56	**57.44**
(Row %)	*(92%)*					*(8%)*	***(100%)***
(Column %)	*(91%)*						
Small beam trawlers	0.33	22.67	1.78			2.11	**26.89**
(Row %)	*(1%)*	*(84%)*	*(7%)*			*(8%)*	***(100%)***
(Column %)	*(1%)*	*(86%)*	*(5%)*				
Shrimp beam trawlers		2.78	31.22	1.00	0.22	3.67	**38.89**
(Row %)		*(7%)*	*(80%)*	*(3%)*	*(1%)*	*(9%)*	***(100%)***
(Column %)		*(11%)*	*(88%)*	*(12%)*	*(8%)*		
Otter trawlers	0.11	0.44	0.89	6.89	0.00	0.89	**9.22**
(Row %)	*(1%)*	*(5%)*	*(10%)*	*(75%)*	*(0%)*	*(10%)*	***(100%)***
(Column %)	*(0%)*	*(2%)*	*(3%)*	*(85%)*	*(0%)*		
Trammel netters			0.11		2.33	0.11	**2.56**
(Row %)			*(4%)*		*(91%)*	*(4%)*	***(100%)***
(Column %)			*(0%)*		*(84%)*		
Outside industry	4.56	0.56	1.56	0.22	0.22		
(Column %)	*(8%)*	*(2%)*	*(4%)*	*(3%)*	*(8%)*		
Total	**57.89**	**26.44**	**35.56**	**8.11**	**2.78**		
(Column %)	***(100%)***	***(100%)***	***(100%)***	***(100%)***	***(100%)***		

(Source: Own data)

2.4 Discussion

Empirical strategic group research has primarily focused on defining strategic groups within single industries to examine whether performance persistently differs across these groups and affects overall industry performance (e.g., Cool *et al.*, 1987; Fiegenbaum *et al.*, 1993; Fombrun *et al.*, 1987; Frazier *et al.*, 1983; Harrigan, 1985; Hatten *et al.*, 1977; Hawes *et al.*, 1984). Additionally, research has also habitually examined if strategic groups are subject to "changes" over time, such as whether group membership shifts, or if the number of strategic groups changes. The objectives of our study are in line with these central research questions in strategic group research. This study borrows the concept of strategic groups together with its theory from the field of strategic management and applies it to the case of the Belgian fishing fleet. Consequently, five strategic groups in the Belgian fishing fleet are defined based on their competitive advantages arising from the source of their mobility barriers (i.e., the state of their resource configuration). As a result, this finding rejects the first hypothesis, "all the vessels of the Belgian fishing fleet belong to the same strategic group". In deriving these strategic groups cluster algorithms were used based on excessive within- and between-method triangulation (Ketchen *et al.*, 1996). This resulted in highly valid cluster solutions. The within-method triangulation of a two-stage clustering procedure combining hierarchical- with non-hierarchical clustering (known in the literature for its increased validity of the cluster solution (Ketchen *et al.*, 1996; Milligan, 1980; Punj *et al.*, 1983)) has also increased the validity of the cluster solutions in this case. Furthermore, this study expands the between-method triangulation with the use of discriminant analysis in addition to the commonly suggested analyses of variances on external variables (Ketchen *et al.*, 1996). This idea of using discriminant analysis was borrowed from other fields like market research (Rason *et al.*, 2007) and geography (Power *et al.*, 1992).

Next, this study finds differences in the performance across most of the strategic groups, which rejects our second hypothesis, "all strategic groups perform the same". This finding not only assesses the criterion validity of the obtained cluster solution, it also contributes to the discussion in the strategic group research on the existence of a "group membership-performance link" (Barney *et al.*, 1990). Although strategic group research is still unable to consistently find this link (Cool *et al.*, 1988; Ketchen *et al.*, 1997), this study proves that in the case of the Belgian fishing fleet the group memberships-performance link does persist.

Related to the third and fourth hypotheses on group membership and group loyalty, the results unveil that most vessels remain a member of their strategic group for many years. Hence, vessels do not often shift between strategic groups. This finding is in line with the results of previous studies (Cool *et al.*, 1987; Fiegenbaum *et al.*, 1990b, 1993; Oster, 1982) and the theory of the existence of mobility barriers between strategic groups that deter or inhibit the movement of a firm from one strategic group to another (Caves *et al.*, 1977). As a result, the resources used to define the strategic groups (i.e., technology, product range and geographic reach) are important sources of mobility barriers and therefore quite valuable in unveiling the strategic groups' competitive advantages. However, not every strategic group enjoys the same level of group loyalty since significant differences are observed across the strategic groups concerning firm movement. This results in the rejection of the fourth hypothesis. Although this is definitely a topic for further research, a possible interpretation for this phenomenon is the theory of asymmetric mobility barriers (Caves *et al.*, 1977; Harrigan, 1985; Hatten *et al.*, 1987) in combination with a firm's "isolating mechanisms" (Rumelt, 1984).

Asymmetric mobility barriers mean that not all mobility barriers seem to be equally high between strategic groups. Consequently, some shifts between strategic groups are more easily made than others because they require an accumulation of one or more resources which is not too costly or risky. The results on the average yearly firm movement across strategic groups between pairs of adjacent years illustrated that small beam trawlers and shrimp beam trawlers often shift between these strategic groups. These shifts only require the purchase of a new fishing net and successful targeting of other species. Further inquiry also illustrated that there is often a "back-and-forth"-move between these strategic groups. This can be mainly explained by the fact that in some years small beam trawlers may have had caught a lot of shrimp during the shrimp season and therefore kept targeting them longer than usual. Consequently, cluster analysis allocated them in that year to the strategic group of shrimp beam trawlers instead of small beam trawlers. The inverse pattern exists in the strategic groups of the shrimp beam trawlers. Next, the results on the average yearly firm movement across strategic groups also showed that there is significant firm movement from otter trawlers to both the small beam trawler fleet and shrimp beam trawler fleet. In the first case this requires only the purchase of new fishing gear and being able to use it successfully. In the second case this requires the purchase of new fishing gear and being able to successfully target shrimp. The fact that otter trawler move towards two strategic groups prove that they did not have a second best choice like the "small beam trawlers-shrimp beam trawler"-trade off. Additionally, "back-and-forth"-movement is not observed for the otter trawler fleet since small beam trawlers and shrimp beam trawlers do not or at least not that frequently move back to the otter trawler fleet. Hence, it seems that vessels which have made the shift towards the otter trawler fleet are satisfied with their new strategic direction. Finally, the results of average yearly firm movement across strategic groups illustrates that there are also marginal or absent potential firm movements. This can illustrate that certain shifts are (too) costly or risky. For instance: small beam trawlers whose ambition is to become a member of the large beam trawler group have to invest in a larger and more powerful engine. In addition, the engines will consume more fuel, which will result in higher operational costs. As a result, these small beam trawlers encounter much higher mobility barriers compared to the small beam trawlers who shift to operate as shrimp beam trawlers.

Isolating mechanisms is a second phenomenon that can block firm movement. It means that "individual firms are also constrained by their resource base and the legacy of past investments. These isolating mechanisms represent firm-specific commitments (i.e., resources) that restrict the individual firm's degrees of strategic freedom and thus may prevent a firm from switching from one strategy to another" (Leask *et al.*, 2005: 459). This is for instance the case for the current trammel netting fleet in Belgium. These vessels are often catamarans that have not the capability to tow fishing gear over the sea-bed. Hence, their past strategic decisions have isolated them from any form of beam- or otter trawling. This clearly limits their strategic freedom.

Despite careful attention to reliability and validity in this study, important limitations remain. First of all, the validity of this study outside the Belgian fishing fleet is limited because it is an empirical "single industry/single country"-study. In future research on strategic groups in EU fisheries, researchers could include more than one country in their analysis. Furthermore, future research on strategic groups should also primarily focus on defining strategic groups across multiple countries and/or perhaps multiple (similar) industries. However, such studies would only become possible given a uniform methodology for defining strategic groups across (similar) industries and/or countries. A second limitation of this study may lie in its time horizon. Although ten years is a reasonable timeframe, the authors believe that setting the timeframe at several decades would have identified more different strategic groups (e.g., large otter trawlers) and more group member shifts across strategic groups, as a vessel remains operational for much longer than ten years. This expanded timeframe could perhaps even lead to identifying different resources as the sources of competitive advantages. However, expanding the time frame to decades may be impossible due to data limitations. A third limitation is the absence of the use of "stable strategic time periods" (Fiegenbaum *et al.*, 1990a; Fiegenbaum *et al.*, 1990b, 1993) in our analysis in combination with the use of a fixed number of strategic groups over time. However, these two limitations are permitted since (1) the time horizon of this study is medium term; and (2) group structure has been found to be fairly stable and predictable over modest periods of time (Cool *et al.*, 1987; Fiegenbaum *et al.*, 1990b; Oster, 1982). A fourth limitation is the study's static analysis. Although strategic group research has primarily used different kinds of static analyses (e.g., regression models (Hatten *et al.*, 1977; Hatten *et al.*, 1978; Newman, 1978; Porter, 1979), MANOVA's (Hawes *et al.*, 1984), MANOVA's and regression models (Frazier *et al.*, 1983), or ANOVA's and MANOVA's (Fiegenbaum *et al.*, 1993)), future studies should apply dynamic models in analysing group dynamics (e.g., agent-based models (Gilbert *et al.*, 1999) or system dynamics (Forrester, 1961; Sterman, 2000)). A final limitation of this study may be the labelling of the strategic groups. Labelling each strategic group is a subjective process. This study opted to use the terminology and labels of existing sub fleet classifications where possible. This has the advantage that policymakers will recognize some of the strategic groups. However, it also led to the slightly forced labelling of one strategic group: "the shrimp beam trawlers". In this group, some vessels land only small amounts of shrimp but are very specialised toward some other target species. The label "specialised small beam trawlers" may have been more appropriate here. In addition, this inadequate label also resulted in a slightly counterintuitive outcome: the disappointing performance of shrimp beam trawlers compared to other strategic groups.

This study contributes directly to the fishing industry because it shows ship owners the different performance potentials for the different competitive strategies in the current industry. This allows them to reflect on current business and change strategic course if desired, based on performance indicators. If they are satisfied with their current strategic direction, ship owners can still compare their performance to the average performance of their group peers allowing them to evaluate how they are performing within their strategic group. However, the main contribution of this study lies in its value for fisheries management. The authors believe that strategic group theory could be used to simplify fisheries management and its regulation. Fiegenbaum *et al.* (1988: 21) state that "identifying the strategic dimensions that define strategic groups is a key issue in understanding how competitors formulate their strategies" and that "strategic groups help us understand which firms compete strongly with each other"**.** Consequently, knowing these strategic differences between firms within the same industry is crucial when managing fisheries and implementing public policies (Oster, 1982: 376). As a result, policymakers should start defining strategic groups within fisheries and use them as the basis for regulation instead of using (1) tremendously detailed taxonomies of sub fleets solely based on technical characteristics (i.e. fishing methods, gear modifications and mesh sizes) (EC, 2002) or (2) overly specified classification systems based on métiers (EC, 2008) which probably need simplification (i.e., aggregation of métiers in fleet segments) if they want to be workable in practice. Moreover, this strategic group approach shall result in a more strategic form of regulation: the regulation will be more focused on (1) affecting strategic groups' competitive advantages (i.e., mobility barriers), (2) affecting "isolating mechanisms" of firms, and (3) managing rivalry between strategic groups. In addition, the range of policy instruments should be limited to those affecting efficiently the sources of the mobility barriers between strategic groups, altering individual vessels or a strategic group's position within its strategic space. In conclusion, the authors believe that the use of strategic groups can be a way towards simplifying the current Common Fisheries Policy of the European Union. But this study should only be seen as a first introduction of the concept of strategic groups to fisheries management science and fisheries science in general.

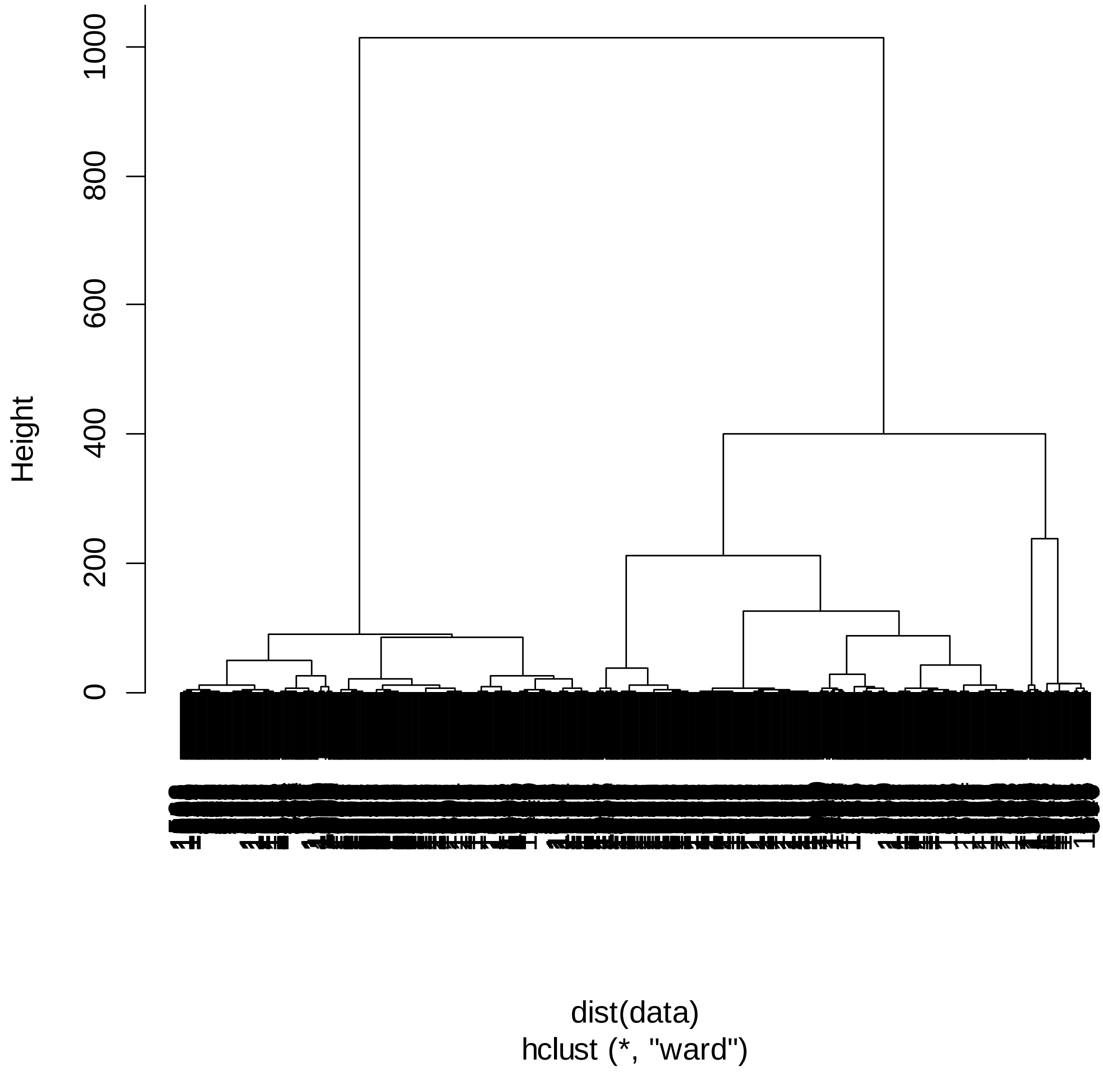
2.5 Conclusion

This study borrows the concept of strategic groups, along with its theory from the field of strategic management, and applies it to the case of the Belgian fishing fleet. As a result, it defines five strategic groups in the Belgian fishing fleet based on their competitive advantages arising from the source of their mobility barriers (i.e., the state of their resource configuration). In addition, it shows that these strategic groups have significant differences in performance. As a result, this study proves that for the case of the Belgian fishing fleet the "group memberships-performance" link persists. Furthermore, in terms of firm movement and group loyalty, this study finds that most vessels remain a member of their strategic group for many years. Strategic groups are therefore very stable over time in the Belgian fishing fleet, but not every strategic group has this high level of "group loyalty". Although this is definitely a topic for further research, a possible interpretation for this phenomenon is the theory of asymmetric mobility barriers (Caves *et al.*, 1977; Harrigan, 1985; Hatten *et al.*, 1987) in combination with a firm's "isolating mechanisms" (Rumelt, 1984).

The value of our study lies in its contribution to fisheries management. The authors believe that strategic group theory could be used to improve fisheries management together with its regulation. Strategic group theory offers fisheries management a strategically grounded theory for developing fishing fleet taxonomies. These taxonomies divided the fleet in strategic groups, each with a unique state in resource configuration and competitive strategy. Such a strategic exercise, along with the way in which strategic groups are defined, will help us better understand competition and rivalry in fisheries. As a result, fisheries management should focus on regulating the competition between these strategic groups. However, further research will be vital in convincing policymakers of the value of strategic groups to manage fishing fleets. For EU fisheries policy, a crucial step will be to shift the focus from a single country study to one incorporating many EU countries. In addition, research should also focus on the origin of the shifts between strategic groups. Future questions could be, "What are the internal or external causes driving vessels to move between strategic groups? And to what extent are such moves motivated by performance differences?" Finally, future strategic group research in fisheries should also apply dynamic models in analysing strategic group dynamics. Two potentially interesting modelling approaches are (1) agent based modelling (Gilbert *et al.*, 1999), or (2) system dynamics (Forrester, 1961; Sterman, 2000) .

2.6 Appendix

Appendix 1: Dendrogram of the hierarchical clustering using Ward's method and Euclidean distance, 1997-2006



(Source: Own data)

Appendix 2: The cluster solution of the hierarchical clustering using Ward's method and Euclidean distance (Mean), 1997-2006

	Cluster	1	2	3	4	5
	N	605	237	393	68	26
Technology	% beam trawling	0.39	0.18	0.06	-3.25	-3.14
	% trammel netting	-0.14	-0.14	-0.14	-0.14	7.00
Product range	# Species/trip	0.77	0.23	-1.24	0.00	-1.33
Geographic reach	kW	1.03	-0.87	-0.94	-0.59	-0.38

(Source: Own data)

Appendix 3: The cluster solution of the k-mediods clustering (Median), 1997-2006

	Cluster	1	2	3	4	5	Sig.
	Clusters labels	Large beam trawlers	Small beam trawlers	Shrimp beam trawlers	Otter trawlers	Trammel netters	
	N	574	277	367	85	26	
Technology	% beam trawling	100[c]	100[b]	100[b]	0[a]	0[a]	.000
	% trammel netting	0[a]	0[a]	0[a]	0[a]	100[b]	.000
Product range	# Species/trip	19.11[d]	15.28[c]	3.90[a]	13.08[b]	4.20[a]	.000
Geographic reach	kW	882[e]	221[b]	218[a]	221[c]	382[d]	.000

Different superscripts (a–b–c–d–e) indicate significantly different average means using Kruskal-Wallis and Mann-Whitney U as post hoc test both with Bonferroni adjustment (α'= 0.005 since k=5).

(Source: Own data)

Photo: One of the many scientific expert group meetings held in developing my microworld (©Kevin Vanhalst - ILVO)

Chapter 3: Simulating the fisheries system with its management system

3.1 Introduction

Since the beginning of the 20th century, fisheries worldwide have been the subject of many modelling exercises (Arnason, 2007). The overall aim of these models is to assist in solving the problem of inefficient use of fish (aquatic) resources. Over the decades, an evolutionary pattern can be observed throughout modelling fisheries. In the 1930s, when fisheries modelling was primarily the domain of fisheries biologists, the focus was on the fish stocks, their total size and cohort structure, and how they changed over time (e.g., Graham, 1935; Russell, 1931). These models were thus called biological models. In the (late) 1950s, biological models were expanded toward bioeconomic models, which included the interactions between the fish stocks and the industry (e.g., Crutchfield, 1956, 1959; Gordon, 1953, 1954; Scott, 1955). Such models combined biological and profit function models but still considered fisheries regulation to be a set of exogenous variables. Further, bioeconomic models also dealt with little intra-industry and/or human behaviour. In the 1980s, these two shortcomings were addressed with the emergence of the political bioregunomics approach to fisheries management (e.g., Anderson, 1987; Walters, 1980) and research on fleet dynamics, respectively. The political bioregunomics approach to fisheries management (e.g., Anderson, 1987; Walters, 1980) resulted in three types of models. All three include parts of the "fisheries management regime" (Arnason, 2007) as endogenous variables: (1) management models assisted in selecting or designing the "best" fisheries management system; (2) fisheries enforcement models extended these management models by including enforcement of management rules; and (3) comprehensive fisheries models extended fisheries enforcement models by including penalty structures. Research on fleet dynamics resulted in an increased understanding of the role intra-industry and human behaviour plays in the exploitation of aquatic resources (e.g., Gillis, 2003; Helu *et al.*, 1999). Its four main research areas are: (1) investment and disinvestment decisions, (2) effort allocation, (3) harvesting efficiency, and (4) discarding and fish mortality (Hilborn, 1985). As a result, fleet dynamic models became very important for fisheries management science. They have become important to all involved with strategic issues related to the future potential of fisheries and fishing fleets in particular.

As in many research fields, these fisheries models can be divided into theoretical and empirical models. The difference between these two types of models is that theoretical models do not have any particular empirical content. They do not contain a description of any particular fishery, only fisheries in general (e.g., Clark *et al.*, 1979; Clark *et al.*, 1982; Gordon, 1954; Scott, 1955; Smith, 1968, 1969; Turvey, 1964). Empirical models, on the other hand, contain a specific empirical description of the features of one or more particular fisheries. A third category of fisheries models exists that partly overlaps the previous two: numerical models. These models contain numerical descriptions of the subject and, as a result, are capable of producing numerical outcomes. While most empirical models are numerical, theoretical models are usually not, but this is not always necessary (for an overview of empirical and numerical models also see: Le Roch, (no date); Rodrigues, 1990).

Fisheries models can also be broadly classified into four types based on their intended purposes: (1) optimisation models; (2) short-term impact assessment models; (3) dynamic simulation models; and (4) microworlds. Optimisation models determine the "optimal" level of key variables depending on a range of assumptions. They are configured to answer "What's best?" questions (Tingley, 2005). Optimisation models frequently attempt to maximise factors such as profit, employment, crew share or fleet size for the entire industry subject to a range of constraints like pre-specified fishing grounds and target species, total allowable catches, minimum profit margins, and days at sea (e.g., Arnason *et al.*, 1997; 2000 and the EMMFID model). Short-term impact assessment models are mainly used to determine the impact of a change in key variables from one time period to the next. As a result, they answer questions such as: "What's the impact of….?" (Tingley, 2005). Short-term impact assessment models are used to assess the economic impact for fishing industries when changes occur such as alteration in total allowable catches (TAC's) (e.g., the EIAA model explained in Salz *et al.*, 2000) or reductions in fleet capacity (e.g., the USA West Coast groundfish fishery model explained in Scholz, 2003). Dynamic simulation models are developed to provide a dynamic simulation framework for considering interactions between key variables over the longer term (i.e., 5-15 years) and to answer questions such as "What happens if…?" (Tingley, 2005). Dynamic simulation models have been developed by the FAO, for instance. These models are applied to a variety of fisheries to predict fleet performance as a function of fishery management measures (e.g., BEAM4 explained in FAO, 2009a; Le Roch, (no date); Tingley, 2005). Similar studies have been performed for the (1) English Channel and Celtic Sea fisheries (e.g., the Invest in Fish South West model, explained in CEMARE *et al.*, 2005), (2) the Mediterranean fisheries (e.g., MEFISTO and BEMMFISH explained in Anon., 2001, 2004; Guillen *et al.*, 2004; Tingley, 2005), (3) the Barents Sea fisheries (e.g., ECONMULT explained in Anon., 1992; Eide *et al.*, 1994), (4) Danish fisheries (e.g., TEMAS explained in Sparre *et al.*, 2007), and (5) fisheries around the Italian coastline (e.g., MOSES explained in Arnason *et al.*, 1997), among others. Finally, microworlds allow decision makers to "refresh decision-making skills, conduct experiments, and play" (Sterman, 2000: 34). They are learning laboratories for ex ante evaluation of strategies (De Geus, 1997; Keys *et al.*, 1996). Such microworlds are often based on simple dynamics simulation models equipped with a user-friendly interface. In fact, they lock a dynamic simulation model giving the player of the microworld only a limited amount of input and output objects. In addition, microworlds can be run "step-wise" (i.e., "gaming" or the dynamic decision making mode) or "continuous" (i.e., "simulation" or the policy development mode) (Langley *et al.*, 1996; McCormack *et al.*, 1998; Wolfe, 1975a). Running the microworld "step-wise" allows decision makers to adjust decisions in the microworld after each time step, which is not the case in the policy development mode since this runs the microworld in one time. Examples of the application of microworlds in fisheries are scarce. However, there is one well known microworld, called Fish Banks, Ltd (Meadows *et al.*, 2001), which aims to teach principles of sustainable management of renewable natural resources through the rivalry of competing fisheries. Other lesser-known examples include (1) Moxnes' (1998a; 1998b) microworld on the exploitation of a single cod population in an isolated Norwegian fjord, which proved that not only tragedy of the commons but also misperception of feedback contribute to overexploitation; and (2) Morecroft's (2008; 2007) microworld called "fish and ships" which deals with the puzzling dynamics of fisheries when managing fishing effort.

This brief overview of fisheries modelling helps to positions this study since its objective is to develop a microworld where stakeholders can "play" and gain long-term insights in the effect policy instruments have on the Belgian fisheries system. The approach is a game that is run in a dynamic decision making mode where the players of the microworld are invited to alter policy instruments annually through switches and sliders. The story behind the game is that the player is the only policymaker in Belgian fisheries and needs to maximise votes for the upcoming elections. The way to do this is to demonstrate the policy strategy proposed for that fisheries system for the next 20 years to the various stakeholder groups. This collective group of stakeholders will then give their votes in function of how well the player paid attention to their needs. The needs are captured by (1) total industry value, (2) industry value per vessel, (3) fleet size, (4) industry employment, (5) average wages, (6) government expenses, and (7) estimated fish stock. How well the policymaker scores on each of these objectives is indicated on the interface of the microworld by "status lamps"; a green light indicates excellent performance, so the policymaker gains 20000 votes, yellow light means "can do better" but the policymaker still gains 10000 votes and red means "severe neglect of this objective" and the policymaker then loses 30000 votes. The total amount of votes a player has acquired is then simply the sum of the votes for each of these seven objectives. Finally, the more votes the player has obtained, the better the score and so the higher the chance of becoming re-elected.

The basis for this microworld is a simple dynamic simulation model, equipped with a user-friendly interface (i.e., "flight simulator"), representing the Belgian fisheries system. Hence, it provides a dynamic representation of the changing and interlinked relationships between biological, fishing and economic components extended to incorporate a range of other features like behavioural intra-industry responses to policy instruments and vessel entry/exit decisions (i.e., fleet dynamics). As such, it allows for key variables in the simulation model to be determined endogenously (i.e., it allows for multiple dynamic interactions) (Tingley, 2005). Finally, it is a theoretical simulation model however grounded in empirical research and findings of the Belgian fisheries. As a result, it contributes to strategic management of the Belgian fishing industry where the microworld on top of the simulation model serves as a learning laboratory for ex ante evaluation of possible policy strategies (De Geus, 1997; Keys *et al.*, 1996).

The objective of this chapter is to develop a microworld based on a dynamic simulation model of the Belgian fisheries system. It contains four sections. Section 1, Materials and Methods, starts by defining the concept of "microworld". A justification of the choice of system dynamics as the modelling methodology then follows. Then comes a discussion of the modelling process, and the section ends with an overview of the information and data needed to develop the microworld. Section 2, Results, describes the development of the dynamic simulation model underlying the microworld throughout the different stages of the modelling process. It ends with locking the simulation model up in a microworld based on the gaming setup. Section 3 discusses the simulation model's value, scope, underlying assumptions and limitations. Section 4 then presents the conclusions.

3.2 Materials and methods

3.2.1 Defining the concept of microworld

Papert (1980) used the term "microworld" for the first time, but microworlds are also known under various other names, including "virtual worlds" (Schön, 1983), "synthetic task environments", "high fidelity simulations", "interactive learning environments", "virtual environments", "scaled worlds" (Gonzalez *et al.*, 2005), and "simuworlds" (Keys *et al.*, 1996). This thesis follows Sterman's (2000) definition of microworlds. He defines microworlds as "formal models in which decision makers can refresh decision-making skills, conduct experiments, and play" (Sterman, 2000: 34). As a result, microworlds are based on formal models which Harrison *et al.* (2007: 1232) define as "a precise formulation of the relationships among variables, including the formulation of the processes through which the values of variables change over time, based on theoretical reasoning". In other words, developing a microworld starts with a model of the behaviour of some system the researcher wishes to investigate, in our case the behaviour of the Belgian fisheries system. The next step is to decide between the nature of the microworld being a physical model, a role play, or a computer simulation (Sterman, 2000: 34). The microworld developed in this study is a simulation model. Therefore, the next step is to convert the formal model into a set of equations and/or transformation rules for the processes by which the variables in the system change over time. These equations and/or transformation rules are then translated into computer code that allows it to run the resulting program on the computer for multiple time periods and produce the outcomes of interest (Harrison *et al.*, 2007). Finally, this simulation model is equipped with a user user-friendly interface which locks the model, allowing the prayers to vary only a limited amount of variables over a limited range. This interfact makes interaction with the model easiers for non-modellers.

3.2.2 Choice of simulation methodology

To construct a microworld like this based on a computer simulation model, a broad range of simulation methods exist, which can be classified according to several criteria including: (1) theoretical versus empirical; (2) static versus dynamic; (3) stochastic versus deterministic; (4) continuous versus discrete; and (5) local versus distributed. The choice on the first two criteria has already been made since the microworld is based on a theoretical dynamic simulation model grounded in empirical research of the Belgian fisheries system. The next choice is now related to the third and fourth criteria above. In this case, this roughly equals choosing between (1) discrete-event simulation (e.g., Robinson, 2004) (2) agent-based modelling (e.g., Axelrod, 1997; Epstein *et al.*, 1996; Gilbert *et al.*, 1999) and (3) system dynamics (e.g., Forrester, 1961; Sterman, 2000).

Discrete-event simulation models are stochastic and discrete. These models are not found in fisheries management science because they are more suited to simulating operation systems as they progresses through time for the purpose of better understanding and/or improving those systems (Robinson, 2004). Discrete-event simulation conceptualises such systems as queuing systems. Technically, these simulation models maintain a queue of events sorted by the simulated time in which they should occur. The simulator reads the queue and triggers new events as each event is processed. Events result in entities (e.g., people, tasks, messages, etc.) travelling through "the blocks of a flowchart where they stay in queues, are delayed, processed, seize and release resources, split, combined, etc." (Borshchev *et al.*, 2004: 6).

Agent-based modelling is stochastic and continuous. It is regularly used in fisheries management science as a dynamic simulation method to evaluate policy strategies (e.g., Elliston *et al.*, 2006; Little *et al.*, 2009; McDonald *et al.*, 2008; Soulie *et al.*, 2006). Agent-based modelling simulates the interactions between adaptive autonomous agents with their "personal" attributes on the one hand, and their environment and other agents on the other hand (Macy *et al.*, 2002; Van Dyke Parunak *et al.*). As a result, agent-based models are essentially "decentralised", meaning that the global system behaviour is not modelled directly (Harrison *et al.*, 2007) but emerges "as a result of many individuals, each following its own behaviour rules, living together in some environment and communicating with each other and with the environment" (Borshchev *et al.*, 2004: 6). Consequently, the main advantage of these models is that they are able to capture complex structures and dynamics in the absence of full knowledge about the global interdependencies in the system (Borshchev *et al.*, 2004). Finally, the outcomes from such models can be obtained on individual- or aggregated levels.

System dynamics modelling is a deterministic and continuous modelling approach based on a system of differential equations (Forrester, 1961). It was developed by electrical engineer Jay W. Forrester in the 1950s and draw upon its foundations in engineering control theory (Keating, 1998). The purpose of a system dynamics model is "to improve understandings of the relationships between feedback structure and dynamic behaviour of a system, so that policies for improving problematic behaviour may be developed" (Richardson *et al.*, 1999: 38). As a result, its focus is on dynamic problems in complex feedback systems (Richardson *et al.*, 1999) where it takes the important generic principle that the structure of a system determines its dynamic behaviour and therefore its performance over time (Morecroft, 2008; Richardson *et al.*, 1999). Consequently, this approach looks within a system for the sources of its problem behaviour instead of blaming externalities. In practice, this axiomatic internal point of view results in models of feedback systems that "bring external agents inside the system" (Richardson *et al.*, 1999: 16).

To create such simulation models, system dynamics starts mostly by diagramming the feedback system responsible for causing the dynamic problem. Two kinds of diagrams are common in system dynamics literature: (1) causal-loop diagrams (CLDs), and (2) stock and flow diagrams (SFDs). CLDs map the interconnections and delays between causes and effects underlying the dynamic problem in a combination of balancing and reinforcing loops. These CLDs are most often used in early stages of model conceptualisation and in later intuitive descriptions of model structure for nontechnical presentations. SFDs drill deeper into the CLDs to match "more closely a complete quantitative description of a model" (Richardson *et al.*, 1999: 25). Feedback loops are now formed when "stock and flow networks interact through causal links, in other words when the inflows and outflows of one asset stock depends, directly or indirectly, on the state and size of other asset stocks" (Morecroft, 2008: 66). As a result, system dynamics abstracts from single events and aggregates "agents or entities" in homogenous asset stocks. Finally, these SFDs are in a later step translated toward "friendly algebra" (Morecroft, 2008: 111) which allows simulation.

This study opts to use system dynamics. Several reasons underpin this choice. First, the interactions between policy instruments and the fisheries system contain multiple interlocking feedback loops which can be clearly and visually presented by using CLDs and SFDs. Second, this visual way of model conceptualisation and building in combination with the "friendly algebra" helps stakeholders to become involved in the modelling process. It allows stakeholders to discuss a complex and non-linear microworld. Consequently, the simulation model is no longer a mathematical black box, but is designed as a tool to enhance learning, which is the aim of this study. Finally, system dynamics software packages also offer plenty of options for graphical interfaces. These make the microworld on top of the simulation model more attractive and much easier to handle.

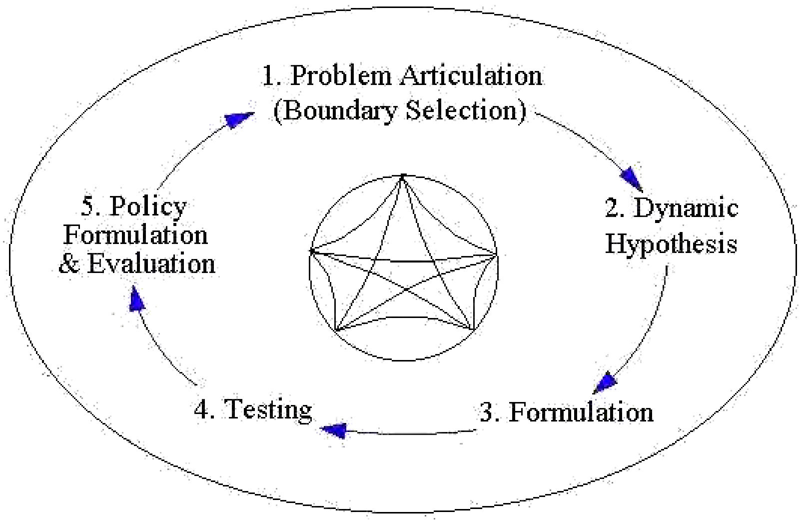
System dynamics is not new to the field of fisheries management science, nor to strategic management (for an overview of system dynamics and strategy see Gary *et al.*, 2008). Although much scarcer in the field of fisheries management science, examples are (1) Meadow's (2001) Fish Banks, Ltd; (2) Morecroft's (2008; 2007) microworld on "fish and ships"; and (3) Moxnes' (1998a; 1998b) study on the contribution of misperception of feedback to the overexploitation of fish resources. In addition, the latter also applied system dynamics to evaluate harvesting strategies (Moxnes, 1999) and used it for policy sensitivity analysis in simple and cohort fishery models (Moxnes, 2005). Dudley (2008) applied system dynamics as a methodological basis for understanding fishery management dynamics. Lastly, Maes *et al.,* (2007) used system dynamics to model the relation between shrimp fisheries and the sand and gravel extraction activity in a perspective of sustainable development.

Last, a choice needs to be made between a local versus distributed approach in modelling method, building a model for a single computer versus one which can or should be run on a network of interconnected computers (possibly through the internet). This study will use the local approach, as there is no need to run it through a network of interconnected computers as there is no form of interaction through the microworld amongst players.

3.2.3 The modelling process

As a result of choosing system dynamics, this study needs to follow its modelling process. The purpose of the modelling process is eventually to "produce a model highly consistent with the real system, well suited for its purposes, and well understood" (Richardson *et al.*, 1999: 293). In system dynamics, the modelling process is iterative but five distinct steps can be identified: (1) problem articulation, (2) defining the dynamic hypothesis, (3) formulation, (4) testing, and (5) policy formulation and evaluation (Morecroft, 2008; Sterman, 2000) (Figure 3.1). Since this study follows these steps, each step except for the last is discussed briefly below, because policy formulation and evaluation is not part of this chapter.

Figure 3.1: Iterative modelling process in system dynamics



(Source: Sterman, 2000: 87)

The first step in the modelling process is "problem articulation". Since system dynamics focuses on tackling specific problems in systems rather than just capturing those systems, it is the most important step because it shapes the entire study. All problems addressed in system dynamics have at least two features in common. First, they are dynamic: "they involve quantities which change over time" (Richardson *et al.*, 1999: 1). As a result, they can be explained in term of graphs of variables over time. Second, these dynamic problems arise in feedback systems (Richardson *et al.*, 1999). Therefore, specifying the time horizon over which the dynamic problem unfolds is an important step since it will (1) influence the simulation model's scope and (2) serve as the length of simulated time over which the simulation model will eventually run (Morecroft, 2008).

After the dynamic problem has been defined with its proper time frame, the system which causes the dynamics problem needs consideration (Morecroft, 2008). Crucial in this is to define the boundary of the system being the imaginary line separating what is considered to be inside the system and what is considered to be outside. Within the system, all concepts and quantities regarded by the study to relate significantly to the dynamics of the problem at hand can be found (Richardson *et al.*, 1999). In drawing the system boundary, special attention is paid to system dynamics' most important criteria for correctly drawing system boundaries: "the closing of feedback loops in the system" (Richardson *et al.*, 1999: 42). However, where exactly to draw the boundary still remains mostly "a matter of judgement and experience" (Morecroft, 2008: 36). To aid in this process, this study uses sector mapping to define the sectors with their interactions that are needed to explain the dynamics of the problem (Morecroft, 2008).

The second step in the modelling process is the formulation of a dynamic hypothesis, being "a working theory of how the problem arose" (Sterman, 2000: 95). It is "a preliminary sketch by the modeller of the main interactions and feedback loops that could explain observed or anticipated performance" (Morecroft, 2008: 106), or "a statement of system structure that appears to have the potential to generate the problem behavior" (Richardson *et al.*, 1999: 55-56). Dynamic hypotheses can be given verbally or in terms of CLDs. Such CLDs are qualitative models, all constructed from the same basic elements: "words, phrases, links and loops – with special conventions for naming variables and for depicting the polarity of links and loops" (Morecroft, 2008: 39) (For more details on how to construct CLDs see chapter 5 of Sterman, 2000). This study states the dynamic hypothesis of this study in a CLD which will also be verbally explained.

Step three is "formulation" which is "the transformation of a dynamic hypothesis into a reasonably detailed diagram of feedback processes and corresponding algebraic equations" (Morecroft, 2008: 106). As a result, this step transforms the informal, conceptual, qualitative view of CLDs into a formal, quantitative representation of SFDs, enabling the simulation model to be simulated (Richardson *et al.*, 1999). Central to the formulation of these SFDs is the identification of "asset stock accumulations" (Morecroft, 2008: 59) which are a kind of memory, "a storage device for material, energy, or information" (Richardson *et al.*, 1999: 176) (e.g., workforce, savings, products and knowledge). Such asset stocks accumulations change according to their inflows and outflows in the same way that "water accumulates in a bathtub" (Morecroft, 2008: 60). Next, the feedback loops between these asset stock accumulations are determined by the "coordinating network" (Morecroft, 2008: 66) consisting of (1) physical flows (similar like in causal linkages in CLDs) (solid arrows), (2) information flows (dotted arrows), (3) convertors (or auxiliaries) and (4) constants (Morecroft, 2008). In building such quantitative models, it is important to incorporate within its structure (1) decision rules which are realistic and "bounded rational" (Morecroft, 1983a, 1983b; Simon, 1976) and (2) criteria for evaluating policies that are used in the real system (Richardson *et al.*, 1999). Finally, there remain two last choices in this step of formulation: (1) the need to disaggregate stocks (i.e., to represent a given asset stock accumulation as a single stock or to disaggregate it into a series of stocks, for instance: the single stock of "fishing vessels" versus the two stocks of "fishing vessels still under depreciation" and "depreciated fishing vessels") and (2) the choice of the right computation interval (i.e., Δt or dt) which is the model time elapsing between computations in the simulation. Disaggregating stocks is tempting and should be avoided simply to make the simulation model look more like the real system. In system dynamics, there are only two cases where disaggregation of stocks is appropriate: (1)

when the disaggregation is required in order for the simulation model to be able to address particular management issues, and (2) when the disaggregation of a stock has the potential to change significantly the behaviour of the simulation model (Richardson *et al.*, 1999). Finally, choosing the right computation interval for the simulation model is a judgmental process. However, a simple rule of thumb sets it between one-half and one-tenth of the smallest time constant occurring in the simulation model (Forrester, 1961; Richardson *et al.*, 1999).

The fourth step is "testing", in which the simulation model is simulated and tested to see whether or not its behaviour over time is plausible and consistent with its assumptions and available evidence from the real world (Keating, 1998; Morecroft, 2008). In this step, errors are fixed and confidence in the model integrity is built. System dynamics adopts a broad and pragmatic view on model validation as a process of confidence building (Forrester *et al.*, 1980). Confidence building involves a variety of different tests to assess the quality of both the model and the modelling process (Barlas, 1996; Forrester, 1973; Forrester *et al.*, 1980; Sterman, 2000). However, three categories of tests have been proven particularly useful in practice: (1) tests of model structure, (2) tests of model behaviour and (3) tests of learning (Morecroft, 2008). Tests of model structure are intended to assess whether the feedback structure and equation formulations of the simulation model are consistent with the available facts and descriptive knowledge of the real system (Morecroft, 2008). These tests apply to both the conceptual model and the algebraic model and are very important in system dynamics practice because structure is central to understanding dynamic behaviour. This study applies the five main tests of model structure: (1) boundary adequacy, (2) structure verification, (3) dimensional consistency, (4) parameter verification and (5) extreme condition test (Morecroft, 2008; Sterman, 2000). The tests of model behaviour are intended to assess how well a model reproduces the dynamic behaviour of interest. The proper use of such tests is to uncover flaws in the structure or parameters of the model and to determine whether they matter relative to the model purpose. Normally, a useful starting point is to ask whether model simulations fit observed historical behaviour. One way to assess goodness-of-fit is to devise formal metrics like (1) mean absolute error (MAE), (2) mean square error (MSE) or (3) Theil's inequality statistics (Theil, 1966). However, since this study is about a simulation model based on Belgian fisheries that is transformed into a microworld containing a gaming setup, these formal metrics lose their value. As a result, qualitative tests of fit are used instead of quantitative tests. Qualitative tests of fit are widely used in practice and consist of "eyeballing the magnitude, shape, periodicity and phasing of simulated trajectories and comparing to past behaviour"(Morecroft, 2008: 400). As a result, it is still possible to "build confidence in model fit by ensuring that simulated trajectories are correctly scaled, pass through recognised data points, have the appropriate periodicity and relative phasing and are consistent with reliable anecdotal information about past behaviour" (Morecroft, 2008: 400). Tests of learning are intended to assess whether model users (in this case gamers) have gained new insights about system structure or learned something new about real system behaviour. Whenever a simulation model provides useful new insights to the stakeholders then it passes the test of learning (Morecroft, 2008). These tests of learning will be the subject of Chapter 5.

3.2.4 Information and data collection

In each of these stages, insights and information were mainly gained from scientific expert group meetings involving fisheries scientists from the Institute of Agricultural and Fisheries Research (ILVO) and myself. These scientific expert group meetings took place on a regular ad hoc basis (roughly bi-monthly) during one year and consisted of three to four experts per meeting. These insights were then verified, when possible, through literature and simple data analyses. Finally, informal contacts with the fishing industry and policymakers have further improved conceptualising the fishing environment more accurately.

To perform the simple data analyses and run the simulation model, data was collected between 1997-2006 concerning (1) the Belgian policy instruments, (2) the fishing environment, and (3) individual vessel characteristics and accounting data. Data on Belgian policy instruments are found in European and national regulations. The latter contains the translation of the European regulations to the Belgian setting, extended with complementary national rules. As a result, only national regulations need to be sought and can be found in the Belgian state papers (often in the form of ministerial decisions). Data on the remaining fishing environment are mainly gathered from two yearly reports published by the Belgian Sea Fisheries Office of the Flemish government: (1) "Belgian marine fisheries: landings and totals" (e.g., Tessens *et al.*, 2004a, 2005a, 2006a), and (2) "Results of Belgian marine fisheries"(e.g., Tessens *et al.*, 2004b, 2005b, 2006b). These reports contain key figures about the condition of the Belgian fisheries (e.g., fish prices and fuel prices) and its fleet. Finally, data on individual vessel characteristics and accounting data were collected from two databases. There is a very useful database called "Belsamp" hosted at the Section Fisheries Biology of ILVO-Fisheries which contains detailed data per individual vessel on catch composition and fishing effort allocation. Financial data on individual vessels came from the Belgian Sea Fishery Office of the Flemish government. They collect accounting data for the Belgian sea fisheries fleet through annual surveys. These surveys are taken on a voluntary basis and they sample on average 50 percent of the fleet (approximately 60 vessels) between 1997 and 2006. However, not all sub fleets of the Belgian fleet are sufficiently present each year. Consequently, additional data was collected through consulting the annual accounts of fishing firms. This resulted in sufficiently high sample sizes for each sub fleet per year.

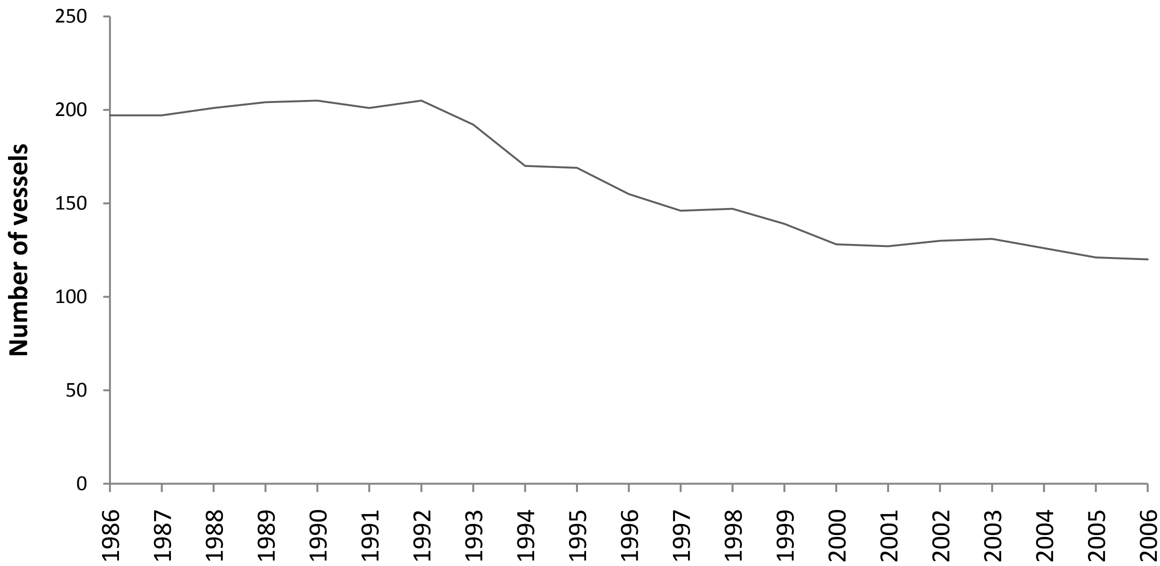
3.3 Results

3.3.1 Problem articulation

The objective of developing a microworld that allows decision makers to "play" and gain long-term insights in the effect policy instruments have on the Belgian fisheries system emerged from the broader observation of a lasting "profitability crisis" in the Belgian fishing industry. As a result, the modelling process started with discussing this current crisis (as of

2006) in the scientific expert group meetings based on graphs of key variables of the Belgian fisheries system over time. When looking at the evolution of the technical characteristics of the Belgian fleet over the last decades, the scientific expert group agreed that, up to the 1980s, the Belgian fishing fleet has gone through a vast conversion. First of all, there was a dramatic decline in fleet size from 457 to 208 vessels between 1950 and 1980. Second, the fleet was converted towards a small but powerful beam trawler fleet operating a highly efficient fishing method for targeting flatfish like sole and plaice. As a result, the Belgian fishing fleet became doubly (over)specialised in both fishing method and target species (Polet *et al.*, 2007). However, this vast conversion together with its sacrifices seemed to have resulted in a fishing fleet which was not longer declining between the eighties and nineties. Hence, this specialisation seemed to have saved the Belgian fleet from depletion. Nevertheless, after more than ten years of having a stable (even a slightly increasing) fleet size, a second decline was setting in around 1992 and still persists (Figure 3.2). This second decline in fleet size, and the role management played or could have played in this crisis, became the focus of our study. As a result, the information in Figure 3.2 served as the starting point for defining the dynamic problem under research.

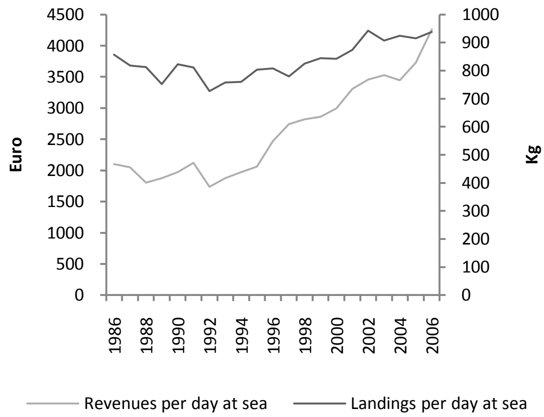
Figure 3.2: Belgian fleet size (#vessels), 1986-2006



(Source: Own compilation, adjusted from Tessens *et al.*, 2006a)

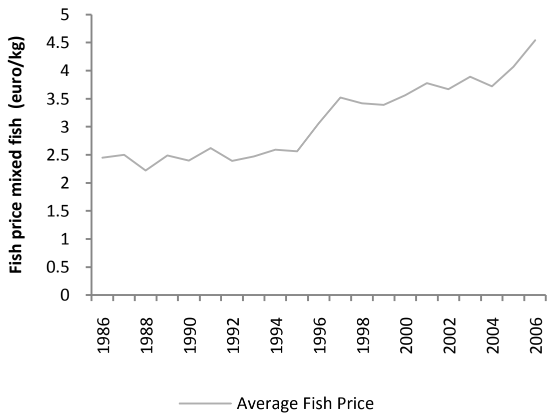
Although financial data over these two decades (i.e., 1986-2006) are limited, further inquiry into the dynamic problem led the experts to look at the performance of the fleet over time. Figure 3.3 illustrates the revenues and landings for an average vessel of the Belgian fleet per day at sea. It shows a declining trend in average landings between 1986 and 1992 with exceptions in 1990 and 1991. However, from 1993 onward, landings increased again, exceeding the 1986 level by almost 10%. In addition, revenues gained from these landings show quite a similar pattern but it is even more promising. First, the slight downfall in landings between 1986 and 1992 has partly been compensated by the increase in prices for Dover sole. Second, the increase in landings from 1993 onward has been reinforced by almost exponentially growing average fish prices (Figure 3.4). As a result, the problem of declining fleet size in Belgian fisheries seems at first glance not to be situated on the revenue side.

Figure 3.3: Revenues (current €) and landings (kg) per day at sea for an average vessel of the Belgian fleet, 1986-2006



(Source: Own compilation, based on data from the Belgian Sea Fishery Office of the Flemish government)

Figure 3.4: Average Belgian fish price (current €/kg), 1986-2006



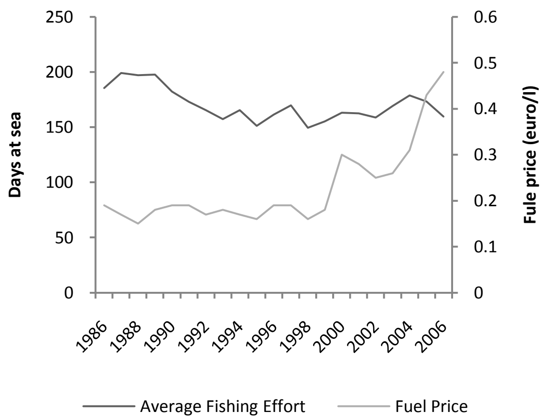
(Source: Own compilation, adjusted from Tessens *et al.*, 2006a)

Investigating the cost side is problematic, as data dates only back to the year 1997. Nevertheless, since labour costs are a fixed fraction (usually 33%) of the revenues, it is clear that labour costs increase directly proportional to the observed increased revenues between 1986 and 2006. Another important cost component is fuel. Cost research on Belgian fleet performance (Polet *et al.* (2006)) states that over 45% of all costs are fuel costs. Additionally, the Belgian Sea Fisheries Office states that in the year 2006 34% and 25% of the revenues of large and small vessels, respectively, were required to cover fuel costs alone (Tessens *et al.*, 2006b)). By combining data on fishing effort with fuel prices, light could be shed on the trajectory of fuel costs between 1986 and 2006. During these two decades, the fishing effort per average vessel tends to decline (Figure 3.5). However, this decline in fishing effort in combination with exponentially increasing fuel prices (Figure 3.5) almost certainly resulted in increased total fuel costs. This reasoning is backed when investigating the figures on fuel costs for the period 1997-2006. As a result, increased costs between 1986 and 2006 could have played an important role in this crisis since they limit opportunities to make profit.

Having observed the trajectories related to revenues and costs of an average vessel of the Belgian fleet, the scientific expert group agreed that fisheries management and regulation played a huge role in the shape of these trajectories because fisheries management is able to alter the fishing environment which results in changes to fleet performance (e.g., Stouten *et al.*, 2008). This fishing environment can be managed by fisheries management systems which Arnason (2009) broadly classifies into two classes: (1) biological fisheries management and (2) economic fisheries management. Biological fisheries management (such as gear restrictions, total allowable catches, area closures, nursery ground protection, etc.) is focused on conserving the fish stocks. Economic fisheries management is further divided into (1) direct restrictions and (2) indirect economic management. The difference between these two categories is that direct restrictions (e.g., the effort restriction of limiting the days at sea, fishing time, holding capacity of vessels, engine size, etc.) impose explicit constraints on the activity of the fishermen, while indirect management merely changes the incentives facing the fishermen. Finally, indirect economic management may be divided into two categories; (1) subsidies and taxes, and (2) property rights (e.g., fishing licences, sole ownership, territorial use rights, individual quota, and community rights).

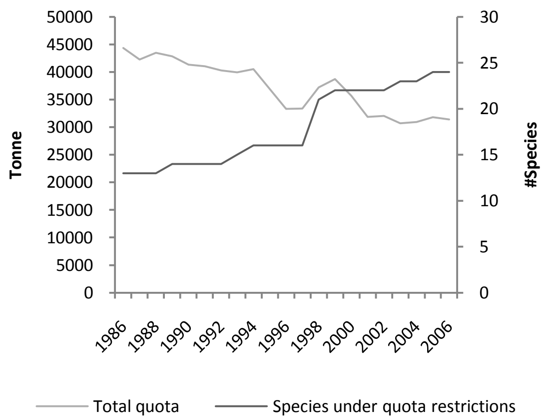
The scientific expert group looked at the main policies Belgium had undertaken between 1986 and 2006. Since fisheries management in Belgium is still mainly based on biologically and directly economically restrictive policy instruments (often imposed by the European Union since Belgium is a member state (EC, 2002)) (Stouten *et al.*, 2008), the scientific expert group first investigated the evolution of the total Belgian fishing quota (i.e., cumulative quota across species and fishing grounds) and the number of species under quota restrictions (i.e., a small computation error is made by counting a small rest fraction as one species) over the last two decades (Figure 3.6). Between 1986 and 2006, there is a clear increase in the number of species under quota restrictions, from 11 to 24 species. Even though the number of species under quota restrictions has more than doubled, total quota has declined significantly from approximately 39000 to 29000 tonnes (a decline of approximately 25%). In addition, Belgian decision makers have also decreased the total amount of fishing days fishermen are allowed to fish. Between 1997 and 2006, the total amount of fishing days decreased from 285 to 260 days (a decline of around 10%) whereas for the North Sea, a very important fishing ground for the Belgian fishing fleet, the total amount of fishing days even decreased by more than 30% - from 235 to only 160 days. Hence, many of the biological and direct economic restrictive policy instruments have all been intensified during the last two decades.

Figure 3.5: Fishing effort (days at sea) of an average Belgian vessel and average fuel prices (current €/l) in the Belgian fishing industry, 1986-2006



(Source: Own compilation based on data from the Belgian Sea Fishery Office of the Flemish government)

Figure 3.6: Total quota (tonne) and species under quota restrictions (#species) in Belgian fisheries, 1986-2006



(Source: Own compilation based on data from the Belgian Sea Fishery Office of the Flemish government)

Belgium had also applied licencing between 1986 and 2006. Licencing is an indirect economic policy instrument (Arnason, 2009). The licencing, in combination with several decommissioning rounds (2004-2006, with increasing decommissioning fees over the years) aimed to reduce overcapacity by buying out unprofitable vessels and destroying their licences. These decommissioning rounds have definitely accelerated the decline in total fleet size. Furthermore, during those two decades, investment subsidies were also widely granted to modernise older vessels and/or to experiment with other fishing methods. However, the scientific expert group agreed that all these financial stimuli have only resulted in a declining fishing fleet; no significant fleet conversions away from unprofitable fisheries have yet taken place. This insight led us to this study, which focuses on developing a tool to help decision makers gain insight into the effects of policy instruments on the Belgian fisheries system. As a result, “learning” instead of “predicting” became central to this study.

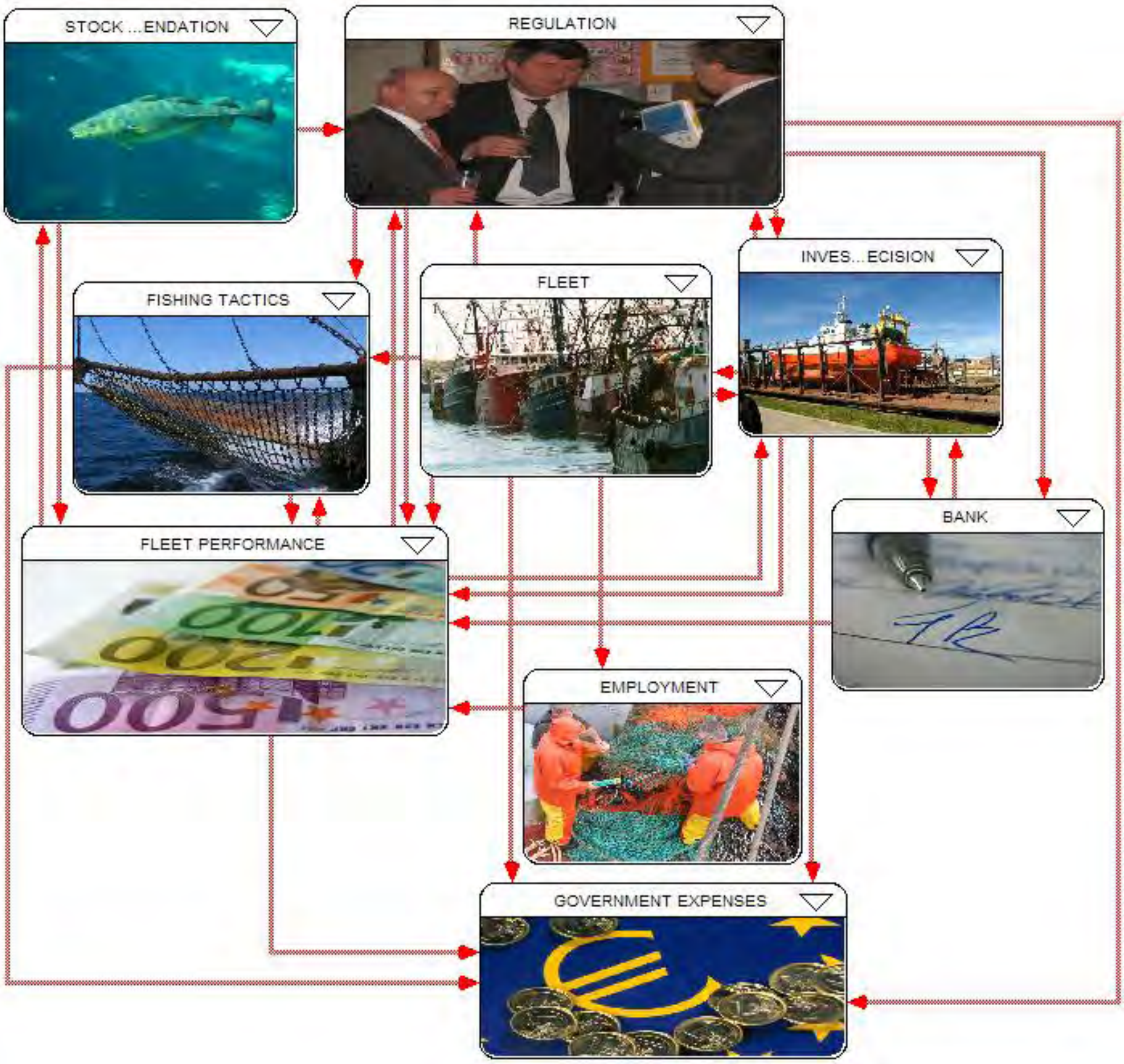
We then consolidated these findings and determined (1) the desired length of simulation time and (2) a sector map. This map defines the scope in the simulation model that will explain the observed behaviour of the previous trajectories and provide long-term insight into the effect of policy instruments on the Belgian fisheries system. First, the desired length of simulation time was set to 20 years. This was based on the information presented in the previous figures; the dynamic problem unfolds over approximately a 20 year time horizon. Second, armed with insights gained from the same information, the experts in the group meetings agreed on the sector map given in

Figure 3.7. It contains nine sectors, with its interactions being: (1) “stock dynamics and quota recommendation”, (2) “regulation”, (3) “fishing tactics”, (4) “fleet performance”, (5) “investment decision”, (6) “bank”, (7) “fleet”, (8) “employment”, and (9) “government expenses”. “Stock dynamics and quota recommendation” captures the puzzling dynamics of

the fish stocks that Belgian fishermen target and the process of making scientific recommendations for total quotas to the policymakers, who in turn set the quotas for the Belgian fishing industry. Hence, this sector interacts with the sector of "regulation" through quota recommendations, but also with the sector of "fleet performance" since dynamics of the fish stock affect catch rates. "Regulation" is the sector that aggregates all Belgian fishing regulation. It contains: (1) quota setting based on the quota recommendations, (2) the allocation of the total quota over Belgium's five sub fleets (3) maximum fishing days, (4) catch restrictions per fishing day, (5) licences, (6) decommissioning fees, (7) investment subsidies, and (8) fuel subsidies and taxes. These eight forms of regulation affect both fishermen's fishing tactics and investment decisions. They also affect the sector "fleet performance" through fuel subsidies or taxes and catch restrictions per fishing day, for example. Third, regulations also have an impact on the sector "bank" since investment subsidies can alter the loans fishermen need when buying new vessels. Finally, some regulations like subsidies and decommissioning fees may also result in government expenses illustrated by the connection between both sectors, the sector of "regulation" and the sector of "government expenses". "Fishing tactics" captures the decision rules on capacity utilisation of the fleet given the regulatory environment, shaped by the sector "regulations", and the estimated Contribution Margin Ratios per sub fleet (Marshall *et al.*, 2003; Milling, 2003) (see below, Equation 16). The effect this sector has on fleet performance and government expenses is through its chosen level of capacity utilisation of the fleet. "Fleet performance" refers to the financial performance of the fleet. It gives insight in: (1) catches (which in this study are set equal to landings), (2) revenues, (3) costs, (4) net profit/losses, (5) savings (i.e., the accumulation of net profit; saved money), (6) debts, (7) value of the vessels of the Belgian fleet, (8) average wages in the industry, and (9) industry value (being industry savings minus industry debts plus the value of the vessels of the Belgian fleet). This sector affects many other sectors. First, it affects "stock dynamics and quota recommendation" through catch rates since catches reduce the fish stock. Secondly, it affects the estimated Contribution Margin Ratios used in "fishing tactics" since these estimates are based on past realised fleet performance. Third, it affects "regulation" since the value of the vessels (which decreases through aging) determines the decommissioning fees. Fourth, it affects "investment decision" since healthy fleet performance may result in investments and unhealthy performance in disinvestment or decommissioning. Finally, it also has an impact on "government expenses" since fishermen may choose to benefit from the given fuel subsidies, for example. "Investment decision" captures the decision rules on buying, selling or decommissioning of vessels. This sector obviously affects the fleet size (i.e., the sector "fleet"). It also affects "regulations" through altering the amount of remaining available licences. Last, it also affects "government expenses" since changes in investment decisions can result in changes in the uptake of decommissioning fees and/or investment subsidies. "Bank" captures the dynamics of the loans the banks are willing to provide; this is mainly a function of estimated future fleet performance. These loans are crucial since buying vessels is almost impossible without such a loan. Hence, they affect the fishermen's investment decisions. Next, loans also affect "fleet performance" since borrowing money results in new debt and interest that both need to be repaid. "Fleet" captures the dynamics in fleet size over time. First, it affects the investment or disinvestment decisions since the state of the fleet size may or may not be the desired one.

Second, it affects "regulations" since it affects the amount of available licences. Third, it affects the performance of the fleet (i.e., the "fleet performance" sector). Fourth, it affects the sector of "fishing tactics" since changes in fleet size may affect capacity utilisation of the fleet. Fifth, it affects industry employment. Finally, it also affects government expenses through the effect a change in fleet size has on the amount of government money that drains away to fuel subsidies. "Employment" is the sector which aggregates all crew members of the vessels. This sector has only an impact on the average wages in the sector (i.e., sector "Fleet performance"). Finally, "Government expenses" aggregates all expenses the government makes through the implementation of (1) decommissioning fees, (2) investment subsidies, and (3) fuel subsidies and taxes.

Figure 3.7: The sector map of the simulation model



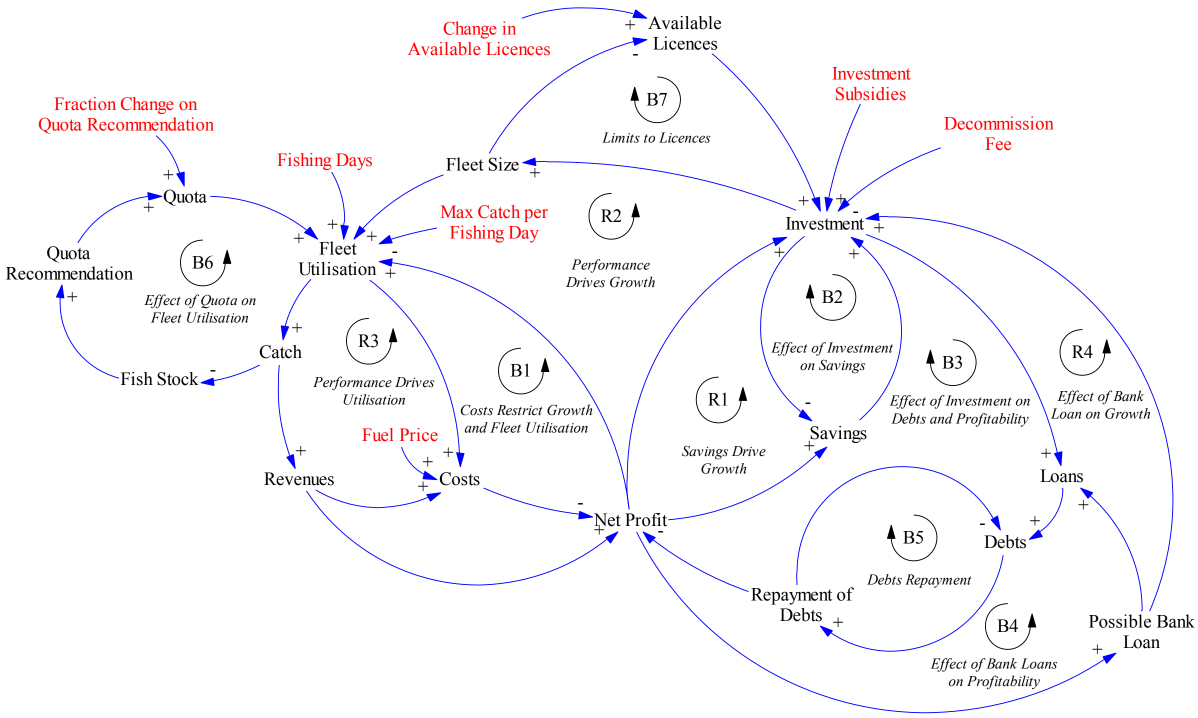
(Source: Own compilation)

3.3.2 Dynamic hypothesis

Once the scientific expert group had defined the scope of the simulation model, they then developed a dynamic hypothesis capturing a deeper understanding of how these sectors interact with each other. The experts agreed on the dynamic hypothesis (the causal loop diagram (CLD) in Figure 3.8). To explain this diagram, it is best to start from R1 and R2, two reinforcing loops that represent growth through investments in an open access fishery with unlimited fish available for harvest. Under these conditions, deploying a larger fishing fleet results in more net profits, which leads to increased savings. Increased savings in combination with higher net profits results in more investments, boosting the fleet size. In addition, increased net profits also drive further fleet utilisation (i.e., R3). However, the costs of fishing are not yet taken into account. B1 (where "B" stands for balancing loop) illustrates the negative effect costs have on net profits and therefore on the reinforcing behaviour of R1, R2 and R3. Next, B2 represents the balancing effect that investments have on savings. However, in reality, investments are not paid in full. Hence, loans (with interest) from financial institutions like banks are necessary to finance these investments. R4 then represents the effect of profitability on getting a loan from the bank. In our simplified case, profitability is taken as a simplified form of a firm's "debt repayment capacity", which normally equals net profit augmented with depreciations minus repayment of debts, but we assume that depreciation equals debt repayment and can therefore be omitted from the formula. Increased profitability leads to being able to get larger loans that will eventually have a positive effect on investments. However, investments also result in increased debt (with interest) that need to be repaid, which in turn decreases net profits (B3). In addition, these debts even increase when profitability increases, because larger bank loans can be obtained (B4). Finally, the effect of debt repayment (including interest) on a regular basis on the amount of debt is given by B5.

Up to this point, the CLD is still based on an open access fishery with unlimited fish to harvest. However, in reality Belgian fisheries are operating in a highly regulated fishing environment. Following the sector map, the selection of policy instruments must be included in the CLD. First, it includes quotas and their effect on fleet utilisation in balancing loop B6. Deployment of a larger fishing fleet results in higher catches, depleting the fish stock. Consequently, a depleted fish stock will lead to recommendations for a lower quota. Lower recommended quotas leads to lower quotas given the same "fraction change on quota recommendation", or the political judgmental factor in the quota setting process. Second, fishing days also affect fleet utilisation through limiting the number of days the fleet can spend at sea. Although this choice is definitely bound by feedback mechanisms, the scientific expert group chose to "open the loops" (Sterman, 2000) related to fishing days. Third, maximum catch per fishing day also affects fleet utilisation since the higher these limits are, the smaller the fleet needs to be to catch the quota given the fishing day restrictions. Fourth, the limiting effect licences have on investment, and therefore on fleet size, is given by balancing loop B7. As a result, the fleet size can only increase if there are licences available, which is a function of (1) changes in fleet size and (2) the applied licence policy. Fifth, policies concerning decommissioning fees and investment subsidies affect investment decisions by stimulating exit and entry behaviour, respectively. Decommissioning fees are determined endogenously in the simulation model as a fraction (i.e., the policy choice) of the remaining value of an old vessel (not given in the CLD). Finally, policymakers can also grant fuel subsidies or levy fuel taxes. Although this is not (yet) the case in Belgium, fishermen see this as a solution for the Belgian fuel-intensive fishing fleet. Hence, the scientific expert group meeting agreed to include this policy instrument in the CLD as well as in the simulation model.

Figure 3.8: Causal loop diagram of the simulation model ("R" = "Reinforcing loop"; "B" = "Balancing loop")



(Source: Own compilation)

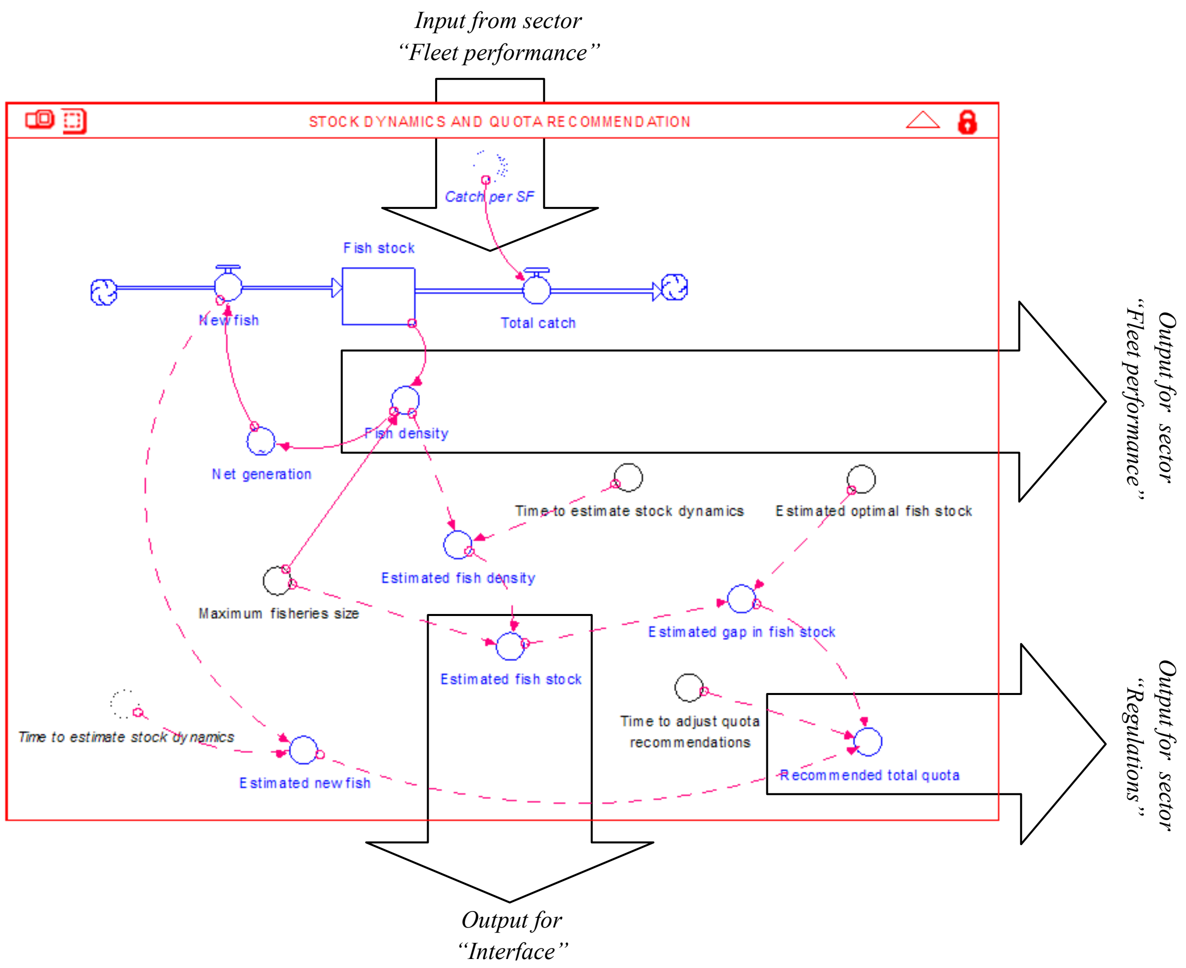
3.3.3 Formulation

The translation of the CLD to the stock and flow diagram (SFD) with its equations is done sector by sector, following the order by which the sectors in the sector map were discussed. But before doing so, two decisions need to be explained and justified. The first decision is related to the need for developing a realistic but simple and transparent simulation model, since complexity can blur or block learning. As a result, only one array is introduced in the simulation model, i.e., the array of sub fleets. The scientific expert group believed that this disaggregation of stocks was required in order for the simulation model to be able to address particular very relevant management issues (related to the diversification of the fleet versus (re)focusing the fleet toward a sub fleet). Hence, the simulation model contains five homogeneous sub fleets as its key agents. The second and more technical decision concerns the choice of time unit and computation interval. The time unit of this simulation model is "years" since most of the policy decisions happen yearly. Its computation interval is set at ¼ of a year, following the abovementioned simple rule of thumb for setting the computation interval (Forrester, 1961; Richardson *et al.*, 1999).

SECTOR 1: STOCK DYNAMICS AND QUOTA RECOMMENDATION

Figure 3.9 is the SFD for the sector on fish stock dynamics and scientific quota recommendation. The scientific expert group meetings pointed out that the dynamic behaviour of a fish stock is still puzzling, subject to extensive research and enormously complex modelling exercises. There are three principal forms of uncertainty in understanding and capturing stock dynamics: (1) fundamental structural uncertainties, (2) parameter uncertainty, and (3) random fluctuations (i.e., "noise") (Charles, 1998). Scientists encounter fundamental structural uncertainties, which reflects a basic lack of knowledge about the nature of stock dynamics. Parameter uncertainty reflects the fact that parameter estimates related to the state of the fish stock are often imprecise and/or delayed. Finally, random fluctuations hamper the process of further inquiry into stock dynamics. This results in a lack of accurate knowledge about the behaviour of the fish stock, although it can be roughly estimated from (1) stock assessment data and (2) quota (ICES, 2008). Consequently, the scientific expert group agreed that the simulation model should reflect these inaccuracies and estimations.

Figure 3.9: Stock and flow diagram capturing stock dynamics and quota recommendation with its in-flows from and out-flows to the other sectors ("SF" = "Sub Fleet")



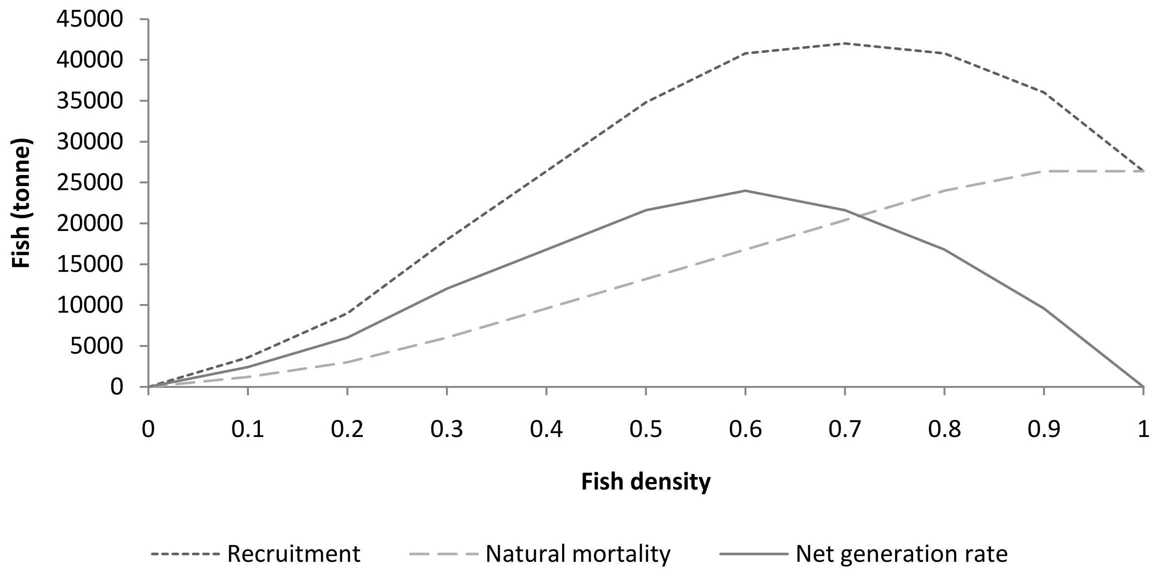
(Source: Own compilation)

In the simulation model, as in reality, the fish stock is thus not known accurately but its value can be roughly estimated. In addition, the scientific expert group made some additional simplifications and assumptions. This simulation model assumes that the Belgian fleet operates in complete isolation. As a result, it is based on a fractional stock dynamics model, equal to Belgium's fraction of all European fleets fishing the same stocks on the same fishing grounds. The scientific expert group opted to include a single species in the simulation model that captures the properties of the different species in Belgian fisheries. Finally, this single species approach is represented in a single asset stock accumulation instead of a more complex cohort structure. The underlying reason for this single stock representation is that the scientific expert group believed that a cohort structure only adds needless complexity to the simulation model. This would not have supported its objective, namely learning about fisheries management. As a result, this study sets the initial value of the total Belgian fish stock B^0 at 40000 tonne fish (see Equation 1 below). Next, $B(t)$ is the fish stock at time *t* which increases through $NF(t)$ and depletes through $C(t)$, being net generation rate of new fish and total catch of the Belgian fleet, respectively, both in time *t*.

$$B(t) = B(t - dt) + (NF - C)dt \quad \{tonne\} \tag{1}$$
$$B(0) = B^0 = 40000 \quad \{tonne\}$$

Where $C(t)$ equals the sum of all the catches of the Belgian sub fleets at time *t*. NF is in reality not yet fully understood because it is related to $B(t)$ which is unknown and this relationship is complex and involves many other variables (i.e., a fundamental structural uncertainty). As a result, the scientific expert group agreed to conceptualise $NF(t)$ as a graphical function based on theory. Hence, $NF(t)$ is a combination of a Ricker's density-dependent stock-recruitment relationship and a density-dependent S-shaped natural mortality rate (Cooper, 2006; Nikolskii, 1969) as given in Figure 3.10. Although this is a very theoretical conceptualisation, similar conceptualisation of NF can be found in other system dynamics studies (e.g., Dudley, 2008; Meadows *et al.*, 2001; Morecroft, 2008) and results in the desired smooth S-shaped growth for a natural fish population, commonly known as "limits to growth" (Randers *et al.*, 1972).

Figure 3.10: Net generation of new fish as a combination of a Ricker's density-dependent stock-recruitment relationship and a density-dependent S-shaped natural mortality rate



(Source: Own compilation)

These stock dynamics then form the basis for quota, which scientists must recommend to Belgian policymakers. The scientific expert group conceptualised quota as to limit total catch steering $B(t)$ toward $B_{msy}(t)$, being its maximum sustainable biomass at time *t*. Although fisheries management has multiple objectives, maximum sustainable yield is a commonly agreed objective for the fish stock found in legislation and international agreements, e.g., Rio Declaration 1992 and Johannesburg Declaration 2002. In this simulation model, $B_{msy}(t)$ is reached when $NF(t)$ is at its maximum which happens when $d(t)$, being the fish density at time *t*, reaches the value of 0.6 (Figure 3.10) with:

$$d(t) = \frac{B(t)}{B^{max}} \quad \{dimensionless\} \tag{2}$$

$$B^{max} = 80000 \quad \{tonne\}$$

Where $B^{max}(t)$ is the maximum value for $B(t)$ also known in fisheries as the carrying capacity. In this simulation model, $B^{max}(t)$ is set as a constant with a value of 80000 tonne fish assuming that the carrying capacity does not change over time (through ecological effects of fishing and/or policy strategies, for instance).

To allow steering $B(t)$ toward $B_{msy}(t)$ or to recommend quota, scientists need to estimate (1) the gap between $B(t)$ and $B_{msy}(t)$ and (2) $NF(t)$, respectively $\widehat{\Delta B}(t)$ and $\widehat{NF}(t)$. $\widehat{NF}(t)$ equals $NF(t)$ smoothed over the assumed time scientists need to estimate $NF(t)$ through surveys (set in this case at one year). To calculate $\widehat{\Delta B}(t)$, the scientific expert group assumed scientists have an accurate idea of the value of $B_{msy}(t)$ (i.e., $B_{msy}(t)$ equals $\hat{B}_{msy}(t)$ and is set constant at 48000 tonne fish) but need to estimate the fish stock ($\hat{B}(t)$) through estimating the fish density ($\hat{d}(t)$) with $\hat{d}(t)$ being $d(t)$ smoothed over the assumed time scientists need to estimate $d(t)$ (in this case one year). Next, $\widehat{\Delta B}(t)$ is then simply calculated as:

$$\widehat{\Delta B}(t) = \hat{B}_{msy} - \hat{B}(t) \quad \{tonne\} \tag{3}$$

Hence, the scientific quota recommendation at time *t* is then obtained by:

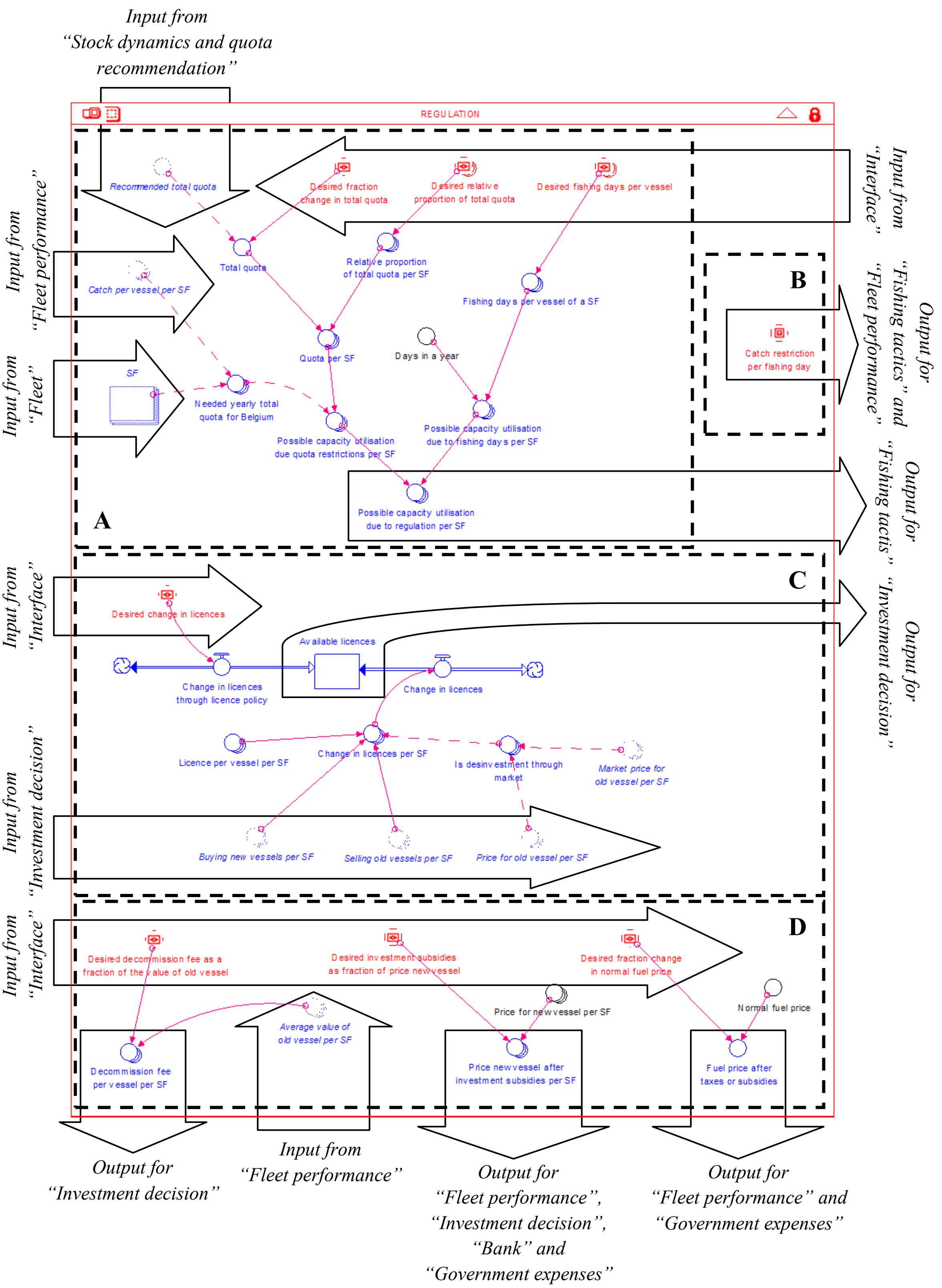
$$Q_r(t) = smth1\left(max\left(\widehat{NF}(t) + \widehat{\Delta B}(t), 0\right), t_{Q_r}\right) \quad \left\{\frac{tonne}{year}\right\} \tag{4}$$

Where "smth1" is a first-order smoothing function and t_{Q_r} is a constant and reflects the time scientists need to adjust their quota recommendations, capturing the time scientists need to believe that $\widehat{\Delta B}(t)$ and $\widehat{NF}(t)$ have structurally changed. In this case, t_{Q_r} is set at one year. Finally, it is $Q_r(t)$ which scientists report to the policymakers who actually set the quota.

SECTOR 2: REGULATIONS

This sector contains the SFD of all the fishing regulations in the simulation model (Figure 3.11). This SFD contains four major parts: (1) "Part A" captures the conceptualisation of quota setting and the setting of maximum fishing days, (2) "Part B" captures the catch restrictions per fishing day, (3) "Part C" captures the dynamics in available licences, and (6) "Part D" captures the conceptualisation of decommission fees, investment subsidies and fuel taxes or subsidies, respectively.

Figure 3.11: Stock and flow diagram capturing the sector on regulations with its in-flows from and out-flows to the other sectors ("SF" = "Sub Fleet")



(Source: Own compilation)

In the simulation model, quota at time t $Q(t)$ are set based on $Q_r(t)$ (see part A of Figure 3.11). However, policymakers who set $Q(t)$ enjoy a certain freedom to agree or disagree with $Q_r(t)$. This process of political judgement is captured in a single variable being the desired fraction change in total quota at time t ($pj^{desired}(t)$). Hence, $Q(t)$ is then given by:

$$Q(t) = Q_r(t)\left(1 + pj^{desired}(t)\right) \quad \left\{\frac{tonne}{year}\right\} \tag{5}$$

The value for $pj^{desired}(t)$ is initially set at zero resulting in $Q_r(t) = Q(t)$ meaning that policymakers fully agree with $Q_r(t)$ and are not sensitive to lobbying from different stakeholder groups.

Next, $Q(t)$ is allocated over the five Belgian sub fleets. As a result, the quota per sub fleet at time t $Q_s(t)$ is conceptualised as:

$$Q_s(t) = \frac{Q(t)}{\max(\sum_s pq_s(t), 1)} pq_s(t) \quad \left\{\frac{tonne}{year}\right\} \tag{6}$$

Where $pq_s(t)$ represents the relative proportion of total quota allocated to sub fleet s at time t which equals in this case the desired relative proportion of total quota allocated to sub fleet s at time t $pq_s^{desired}(t)$. $pq_s^{desired}(t)$ initial values are all set to five. Since these values represent relative proportions of the total quota allocated to each sub fleet, altering one of them affects all others.

Hence, $Q_s(t)$ is a limiting factor of the effective capacity utilisation of sub fleet s at time t $U_s(t)$ (which is obtained in the sector on fishing tactics). A second factor is $n_{days,s}(t)$ being the amount of fishing days sub fleet s gets from policymakers at time t which equals in this case the desired amount of fishing days for sub fleet s. In this simulation model, this desired number of fishing days for the different sub fleets can be set between zero and 365 days but their initial values are all set to 200.

When $Q_s(t)$ and $n_{days,s}(t)$ are obtained, $U_{reg,s}(t)$ being the possible capacity utilisation due to regulation for sub fleet s at time t can be calculated as:

$$U_{reg,s}(t) = \min\left(U_{q,s}(t), U_{days,s}(t)\right) \quad \{dimensionless\} \tag{7}$$

Where $U_{q,s}(t)$ and $U_{days,s}(t)$ are both the possible capacity utilisation for sub fleet s at time t due to respectively quota and fishing days. As a result, $U_{reg,s}(t)$ limits $U_s(t)$. Hence, $U_{reg,s}(t)$ is an output of this sector on regulations and will serve as an important input in the sector on fishing tactics where it has its limiting effect on $U_s(t)$.

In Equation 7, the possible capacity utilisation due to quota for sub fleet s at time t is

$$U_{q,s}(t) = \frac{Q_s(t)}{n_{vessel,s}(t)\; C_s(t)} \quad \{dimensionless\} \tag{8}$$

Where $n_{vessel,s}(t)$ is the number of vessels for sub fleet s at time t and $C_s(t)$ the catch of the sub fleet s at time t.

In Equation 7, the possible capacity utilisation due to fishing days for sub fleet s at time t is

$$U_{days,s}(t) = \frac{n_{days,s}(t)}{n_{days,s}^{max}} \quad \{dimensionless\} \tag{9}$$

Where, $n_{days,s}^{max}$ is a constant and set at 365 days (i.e., all days of a regular year) being the maximum number of fishing days a policymaker can give to a vessel of sub fleet s at time t.

After having limited capacity utilisation of the fleet through regulation, policymakers can also restrict the amount of fish sub fleets are allowed to catch per fishing day (see part B of Figure 3.11). As in reality, the main objective of restricting the catch per fishing day is to spread the quota over the sub fleets and their fishing days. However, since the conceptualisation of this simulation model already spreads the quota over the sub fleets and their fishing days through adjusted utilisation of the sub fleets capacity, the scientific expert group agreed to conceptualise the catch restrictions per fishing day at the "cost-side of the fleet". The logic behind this is that catch restrictions per fishing day force sub fleets to spend more time fishing since catches are restricted. As a result, the variable costs increase since more time is spent on fishing (see the sectors "fishing tactics" and "fleet performance"). The decision on implementing catch restrictions per fishing day is included in this simulation model as a boolean $Z(t)$ taking the value one at time t when catch restrictions are active and zero when inactive for all sub fleets.

Next, policymakers use licences to limit the amount of vessels in the total fleet as illustrated in the SFD of part C in Figure 3.11. The number of available licences at time t $n_{lic}(t)$ is represented as an asset stock accumulation which value changes through two bi-flows. The first bi-flow captures the change in licences through the chosen licence policy at time t $n_{lic,reg}(t)$. A negative value for $n_{lic,reg}(t)$ (only) decreases the number of available licences that are not yet used by fishermen. Consequently, a negative value will not force vessels to leave the fleet. The second bi-flow captures the change in licences as a result of the investment decisions of the different sub fleets at time t $n_{lic,I}(t)$. As a result, the number of available licences at time t is then given by:

$$n_{lic}(t) = n_{lic}(t-dt) + \left(n_{lic,reg} - n_{lic,I}\right)dt \quad \{licence\} \tag{10}$$
$$n_{lic}(0) = n_{lic}^{0} = 0 \quad \{licence\}$$

Where n_{lic}^{0} is the initial value for available licences which is a constant set to zero.

In Equation 10, $n_{lic,I}(t)$ at time *t* is

$$n_{lic,I}(t) = \sum_{s} n_{lic,vessel,s} \left(n_{vessel,buy,s}(t) - \left(n_{vessel,sell,s}(t)\, Y_s(t)\right)\right) \quad \{licence\} \tag{11}$$

Where, $n_{lic,vessel,s}$ is the number of licences per vessel for sub fleet *s* at time *t* which is set constant at one for each vessel independent of the sub fleet, $n_{vessel,buy,s}(t)$ is the number of vessels sub fleet *s* buys at time *t*, $n_{vessel,sell,s}(t)$ is the number of vessel sub fleet *s* sells at time *t*, and $Y_s(t)$ is a boolean taking value one if sub fleets *s* sells its vessels through the market instead of through decommissioning. $Y_s(t)$ is zero in all other cases.

Next, part D of Figure 3.11 illustrates the SFD on how policymakers affect the investment behaviour of fishermen through direct economic stimuli like decommissioning fees, investment subsidies and fuel taxes or subsidies. When policymakers grant decommissioning fees, it is to stimulate fishermen to leave the industry and reduce overcapacity in the fleet. These decommissioning fees are, theoretically speaking, the price government is willing to pay for old vessels given their target of reducing overcapacity. In the simulation model as in reality, the decommissioning fee for an average vessel of sub fleet *s* at time *t* $P_{vessel,dec,s}(t)$ is a fraction of its remaining value at time *t*. As a result, $P_{vessel,dec,s}(t)$ at time *t* is:

$$P_{vessel,dec,s}(t) = df_s^{desired}(t) \frac{V_s(t)}{n_{vessel,s}(t)} \quad \left\{\frac{euro}{vessel}\right\} \tag{12}$$

Where $df_s^{desired}(t)$ is the desired fraction of the average value of a vessel of sub fleet *s* at time *t* which policymakers are willing to pay for an old vessel of sub fleet *s* at time *t*. $df_s^{desired}(t)$ is initially set at zero, but can be varied between zero and one. $V_s(t)$ is the total value of the vessels in sub fleet *s* at time *t*.

When policymakers give investment subsidies in this simulation model, it is to stimulate fishermen to buy new vessels. These subsidies lower the price of a new vessel for sub fleet *s* at time *t* $P_{vessel,new,s}(t)$ toward the price of a new vessel for sub fleet *s* at time *t* after investment subsidies $P_{vessel,sub,s}(t)$ which is given by:

$$P_{vessel,sub,s}(t) = P_{vessel,new,s} - \left(is_s^{desired}(t)\, P_{vessel,new,s}(t)\right) \quad \left\{\frac{euro}{vessel}\right\} \tag{13}$$

Where $is_s^{desired}(t)$ is the desired fraction of the price for a new vessel of sub fleet *s* at time *t* which will be subsidised. $is_s^{desired}(t)$ is initially set at zero, but can be varied between zero and one. $P_{vessel,new,s}$ are constants: they are 2000000, 5000000, 2000000, 1000000, and 1500000 euro for a small beam trawler, a large beam trawler, an otter trawler, a trammel netter and a shrimp beam trawler, respectively.

Finally, although not (currently) the case in Belgium, policymakers can also implement fuel taxes or subsidies (see part D of Figure 3.11). This would mean that policymakers alter the price fishermen need to pay per litre fuel. As a result, the fuel price after subsidies or taxes at time *t* $P_{fuel,reg}(t)$ is then given by:

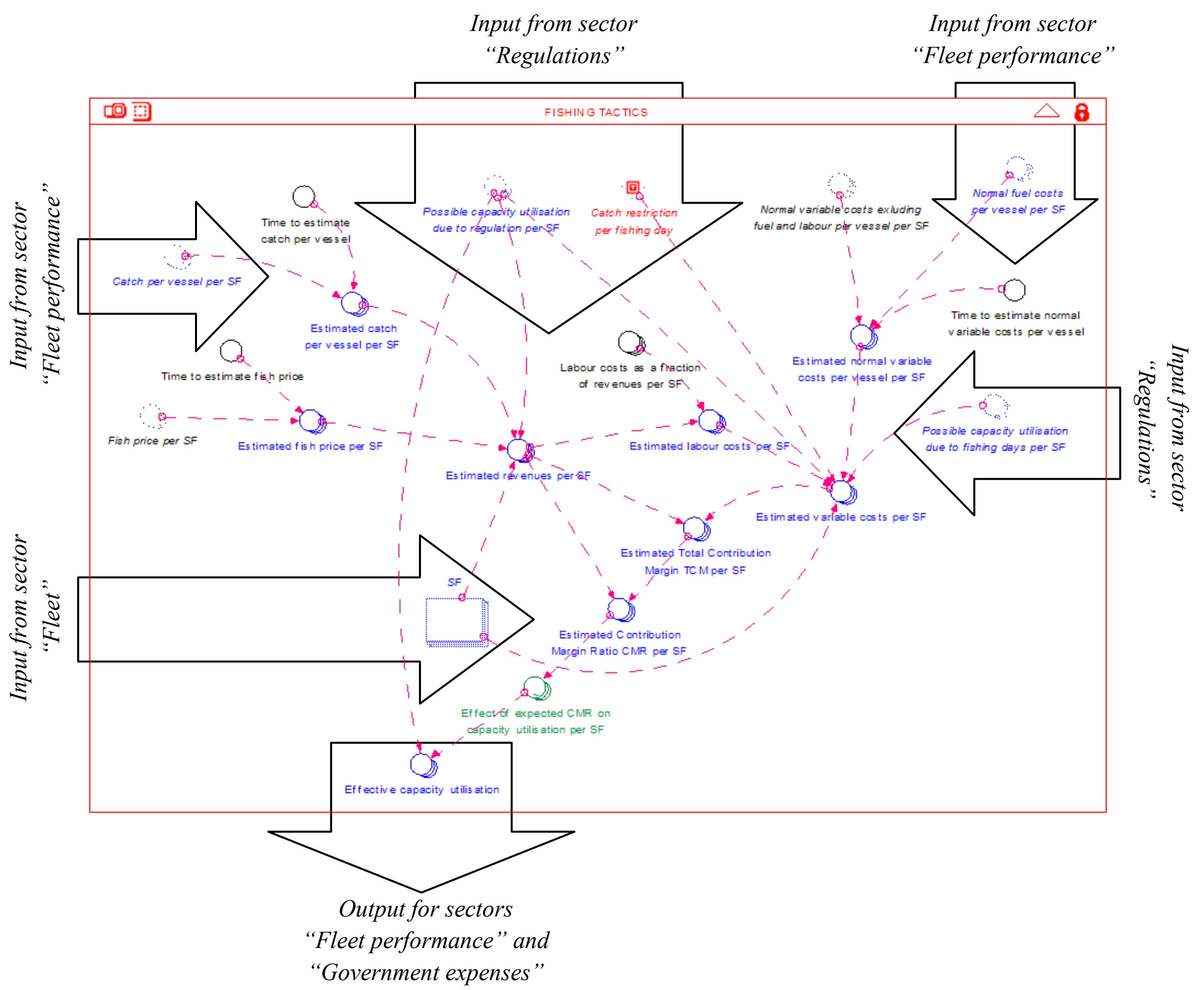
$$P_{fuel,reg}(t) = P_{fuel}\ (1 + f(t))\quad \left\{\frac{euro}{litre}\right\} \tag{14}$$

Where P_{fuel} is the normal fuel price at time *t* which is a constant and set at 0.28 euro per litre. $f(t)$ is the desired fraction of change in normal fuel price at time *t* which equals the fuel subsidies or taxes. Initially, $f(t)$ is set at zero.

<u>SECTOR 3: FISHING TACTICS</u>

The SFD of this sector on fishing tactics is given in Figure 3.12 and determines the value of $U_s(t)$ based on $U_{reg,s}(t)$ and the estimated financial performance when fishing at $U_{reg,s}(t)$.

Figure 3.12: Stock and flow diagram capturing the sector of fishing tactics with its in-flows from, and out-flow to, the other sectors ("SF" = "Sub Fleet")



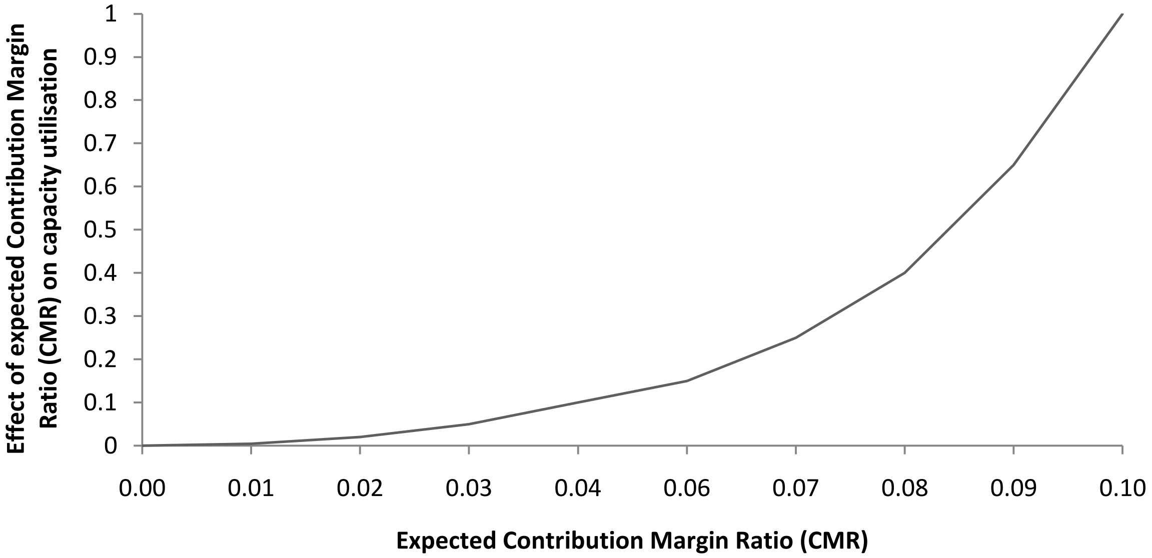
(Source: Own compilation)

In this SFD, the effective capacity utilisation of sub fleet *s* at time *t* is conceptualised as:

$$U_s(t) = U_{reg,s}(t)\ E_{\widehat{CMR},s}(t) \quad \{dimensionless\} \tag{15}$$

Where $E_{\widehat{CMR},s}(t)$ is the nonlinear effect the estimated Contribution Margin Ratio (Marshall *et al.*, 2003; Milling, 2003) for sub fleet *s* at time *t* ($\widehat{CMR}_s(t)$) has on $U_s(t)$. $E_{\widehat{CMR},s}(t)$ is a graphical function and illustrates that when $\widehat{CMR}_s(t)$ lies beneath 0.1 fishermen decide not to fish at $U_{reg,s}(t)$ but at a fraction of $U_{reg,s}(t)$ as given in Figure 3.13. As a result, the conceptualisation of $E_{\widehat{CMR},s}(t)$ reflects the fact that $U_s(t)$ is based on estimates of variables resulting in a decision for $U_s(t)$ which is not "black or white"-decisions as "to fish or not to fish".

Figure 3.13: Effect of Contribution Margin Ratio (CRM) on capacity utilisation



(Source: Own compilation)

To calculate $E_{\widehat{CMR},s}(t)$, the estimated CMR for sub fleet *s* at time *t* is

$$\widehat{CMR}_s(t) = \frac{\hat{R}_s(t) - \widehat{VC}_s(t)}{\hat{R}_s(t)} \quad \{dimensionless\} \tag{16}$$

Where $\hat{R}_s(t)$ are the estimated revenues for sub fleet *s* at time *t* and $\widehat{VC}_s(t)$ are the estimated variable costs for sub fleet *s* at time *t*. This equation as a part of $E_{\widehat{CMR},s}(t)$ assumes that fishermen go fishing as long as they expect that the revenues cover their variable costs. If not, then $U_s(t)$ will be equal to $U_{reg,s}(t)$ multiplied by $E_{\widehat{CMR},s}(t)$.

In Equation 16 and also to calculate $E_{\widehat{CMR},s}(t)$, the estimated revenues for sub fleet *s* at time *t* is

$$\hat{R}_s(t) = U_{reg,s}(t)\ n_{vessel,s}\ \hat{c}_{vessel,s}(t)\ \hat{P}_{fish,s}(t) \ \{euro\} \tag{17}$$

Where $\hat{c}_s(t)$ is the estimated catch for a vessel of sub fleet *s* at time *t* and $\hat{P}_{fish,s}(t)$ is the estimated fish price for sub fleet *s* at time *t*.

Also in Equation 16, the estimated variable costs for sub fleet *s* at time *t* is

$$\widehat{VC}_s(t) = if\left(U_{reg,s}(t) = 0\right) then\ 0$$
$$else\ max\left(Z(t)\ U_{days,s}(t), U_{reg,s}(t)\right)\ \widehat{vc}_{vessel,s}(t)\ n_{vessel,s}(t) + \widehat{LC}_s(t)\ \left\{\frac{euro}{vessel}\right\} \quad (18)$$

Where $\widehat{vc}_{vessel,s}(t)$ are the estimated variable costs (i.e., fuel costs and all other variable costs excluding labour costs) for a vessel of sub fleet *s* at time *t* smoothed over the time needed to estimate these variable costs (in this case one year) and $\widehat{LC}_s(t)$ is the estimated labour costs for sub fleet *s* at time *t*. Table 3.1 illustrates the different outcomes of this equation.

Table 3.1: Overview of the different outcomes of the estimated variable costs for sub fleet *s* at time *t* ($\widehat{VC}_s(t)$) depending on the possible capacity utilisation due to regulation for sub fleet *s* at time *t* ($U_{reg,s}(t)$) and the catch restrictions per fishing day ($Z(t)$)

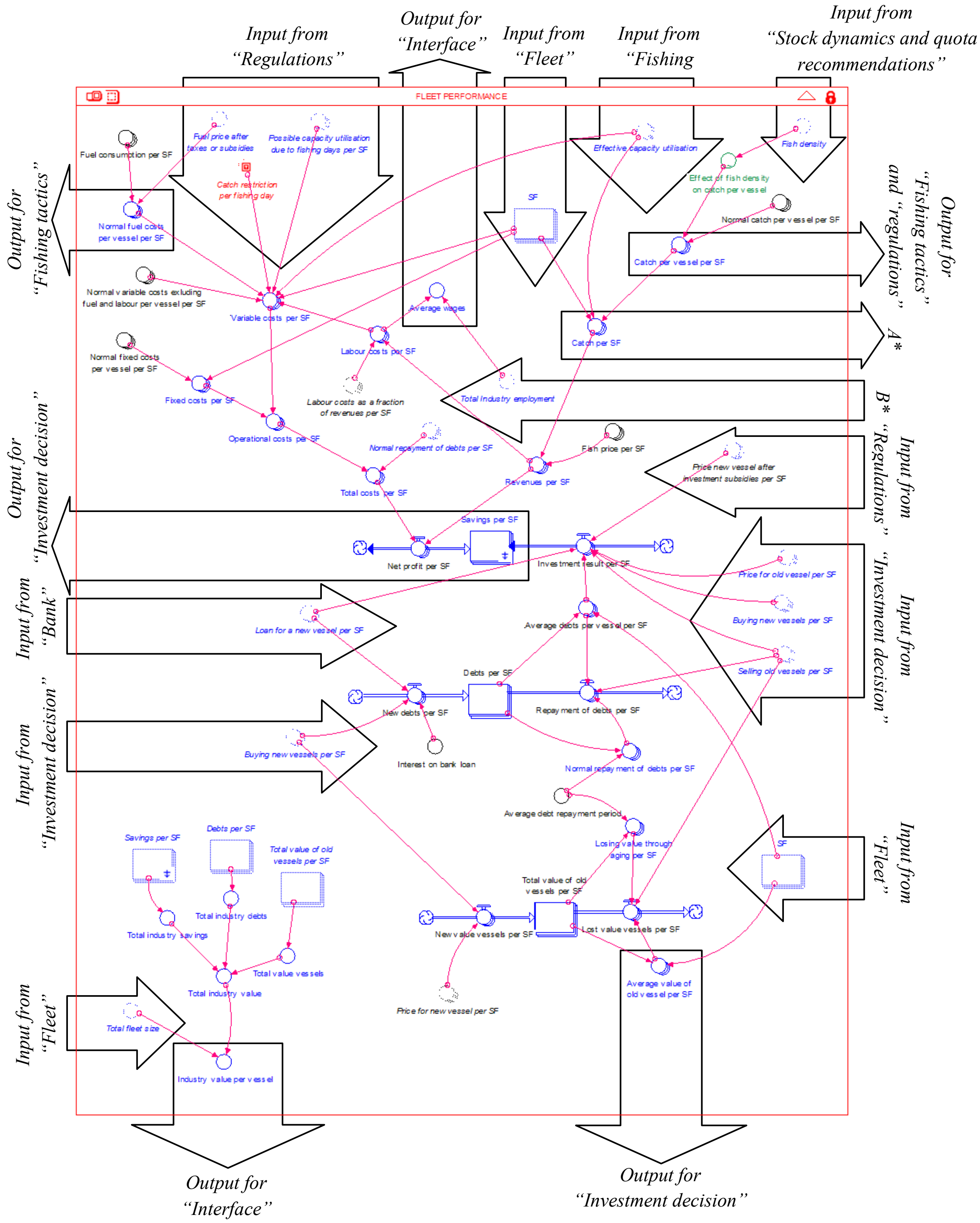
$U_{reg,s}(t)$	$U_{reg,s}(t)$	$Z(t)$	$\widehat{VC}_s(t)$
$\neq 0$	$U_{q,s}(t) < U_{days,s}(t)$	0	$U_{q,s}(t)\ \widehat{vc}_{vessel,s}(t)\ n_{vessel,s}(t) + \widehat{LC}_s(t)$
		1	$U_{days,s}(t)\ \widehat{vc}_{vessel,s}(t)\ n_{vessel,s}(t) + \widehat{LC}_s(t)$
	$U_{q,s}(t) > U_{days,s}(t)$	0	$U_{days,s}(t)\ \widehat{vc}_{vessel,s}(t)\ n_{vessel,s}(t) + \widehat{LC}_s(t)$
		1	$U_{days,s}(t)\ \widehat{vc}_{vessel,s}(t)\ n_{vessel,s}(t) + \widehat{LC}_s(t)$
= 0	All cases	All cases	0

(Source: Own compilation)

SECTOR 4: FLEET PERFORMANCE

Figure 3.14 illustrates the SFD of the sector on the financial performance of the fleet and sub fleets.

Figure 3.14: Stock and flow diagram capturing the sector of fleet performance with its in-flows from and out-flows to the other sectors (“SF” = “Sub Fleet”)



A = Output to “Stock dynamics and quota recommendations”*
B= Input from “Employment”*

(Source: Own compilation)

Crucial in this financial status of the fleet is (1) the total value of the industry at time *t* $V_{ind}(t)$, and (2) the total value of the industry per vessel which simply divides $V_{ind}(t)$ by $n_{vessel}(t)$ being the number of vessels in the fleet at time *t*. As a result, a good starting point for explaining the SFD of this sector is to start with the total value of the industry at time *t* as conceptualised by the scientific expert group as:

$$V_{ind}(t) = \sum_{s} S_s(t) - \sum_{s} D_s(t) + \sum_{s} V_s(t) \quad \{euro\} \tag{19}$$

Where $S_s(t)$ are the savings, $D_s(t)$ the debts, and $V_s(t)$ the total value for the vessels of sub fleet *s* at time *t*.

In Equation 19, the savings for sub fleet *s* at time *t* is an asset stock accumulation which value changes due to two bi-flows. The first bi-flow $NP_s(t)$ represents the net profit for sub fleet *s* at time *t*. Since $NP_s(t)$ can be either negative or positive reflecting net profit or net losses, respectively, $NP_s(t)$ can either deplete or increase the amount of savings for sub fleet *s* at time *t*. The second bi-flow $I_{fin,s}(t)$ captures the financial result of the investment decision for sub fleet *s* at time *t*. Consequently, $S_s(t)$ at time *t* is given by:

$$S_s(t) = S_s(t - dt) + \left(NP_s - I_{fin,s}\right)dt \quad \{euro\} \tag{20}$$
$$S_{sbt}(0) = S_{sbt}^0 = 10 \quad S_{lbt}(0) = S_{lbt}^0 = 25 \quad S_{ott}(0) = S_{ott}^0 = 10 \quad \{million\ euro\}$$
$$S_{tra}(0) = S_{tra}^0 = 5 \quad S_{shr}(0) = S_{shr}^0 = 7.5 \quad \{million\ euro\}$$

Where S_{sbt}^0, S_{lbt}^0, S_{ott}^0, S_{tra}^0, and S_{shr}^0 are the initial values of the savings for respectively small beam trawlers, large beam trawlers, otter trawlers, trammel netters and shrimp beam trawlers.

In Equation 20, the first bi-flow $NP_s(t)$ depends on the outcome of the fishing tactical decision rules for sub fleet *s* at time *t* and is given by:

$$NP_s(t) = R_s(t) - \left(FC_s(t) + VC_s(t) + LC_s(t) + NRP_{debt,s}(t)\right) \quad \left\{\frac{euro}{year}\right\} \tag{21}$$

Where $R_s(t)$ are the revenues of sub fleet *s* at time *t*, $FC_s(t)$ the fixed costs of sub fleet *s* at time *t* calculated by multiplying $n_{vessel,s}(t)$ by normal fixed costs per vessel of sub fleet *s* at time *t*, $VC_s(t)$ the variable costs of sub fleet *s* at time *t*, $LC_s(t)$ the labour costs for sub fleet *s* at time *t* which is as in reality a fraction (i.e., mostly 0.33) of $R_s(t)$, and $NRP_{debt,s}(t)$ the normal repayment of debts for sub fleet *s* at time *t* which is given by dividing $D_s(t)$ by the average debt repayment period, in this case 20 years.

In Equation 21, the variable costs of sub fleet *s* at time *t* are:

$$VC_s(t) = if\,(U_s(t) = 0)\ then\ 0$$
$$else\ max\left(Z(t)\ U_{days,s}(t), U_s(t)\right)\ vc_{vessel,s}(t)\ n_{vessel,s}(t) \quad \left\{\frac{euro}{year}\right\} \tag{22}$$

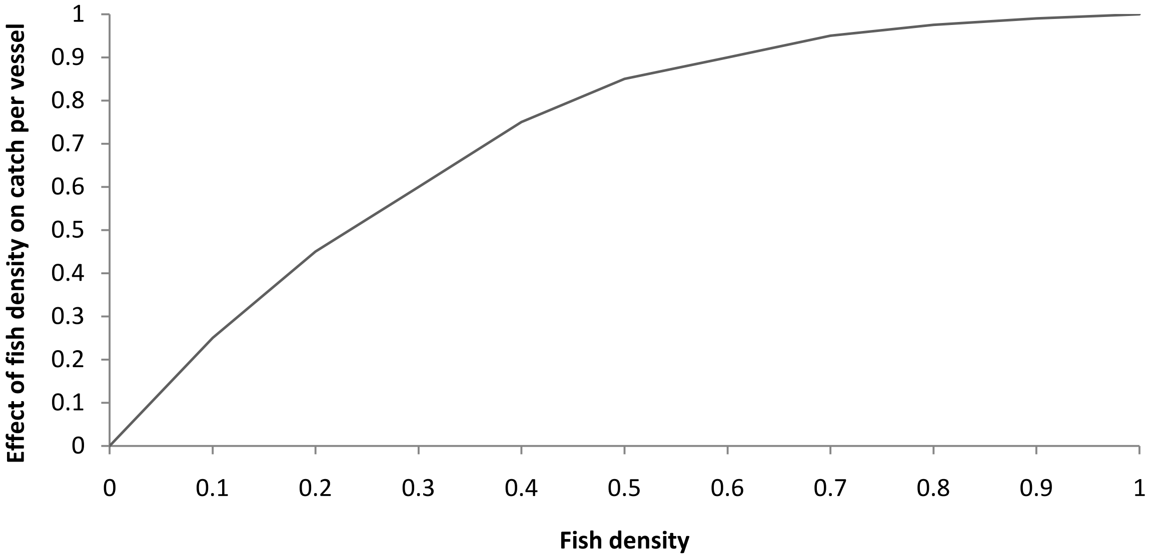
Where $vc_{vessel,s}(t)$ are the variable costs for a vessel of sub fleet *s* at time *t* being the fuel and all other variable costs excluding labour costs. Fuel costs of sub fleet *s* at time *t* are given by multiplying $P_{fuel,reg}(t)$ by the constants of fuel consumption for sub fleet *s* ($n_{fuel,vessel,s}$), being 720362, 1672732, 456192, 155772 and 320776 liters per year for a small beam trawler, a large beam trawler, an otter trawler, a trammel netter and a shrimp beam trawler, respectively. The sum of all the other variable costs excluding labour costs are 150867, 300406, 122283, 115810 and 69808 euro per year for a small beam trawler, a large beam trawler, an otter trawler, a trammel netter and a shrimp beam trawler, respectively. Finally, Equation 22 is similar to Equation 18 with its possible outcomes given in Table 3.1. The only difference is that (1) $U_{reg,s}(t)$ is now $U_s(t)$, (2) the estimated values are now actual values, and (3) labour costs are omitted from the equation.

In Equation 21, the revenues for a sub fleet *s* at time *t* is given by:

$$R_s(t) = U_s(t)\, n_{vessel,s}(t)\, c_{vessel,s}(t)\, P_{fish,s} \quad \left\{\frac{euro}{year}\right\} \tag{23}$$

Where, $c_{vessel,s}(t)$ is the catch per vessel of sub fleet *s* at time *t* and $P_{fish,s}$ is the fish price for sub fleet *s* at time *t* meaning that the fish price differs among the sub fleets reflecting differences in "quality" of their landed fish (i.e., catch composition, size of the fish, freshness, injuries, etc.). Unlike reality, $P_{fish,s}$ are constants in this simulation model with $P_{fish,eur}$ = 3787 euro per tonne, $P_{fish,lbt}$ = 3818 euro per tonne, $P_{fish,ott}$ = 3009 euro per tonne, $P_{fish,tra}$ = 6268 euro per tonne, and $P_{fish,shr}$ = 3431 euro per tonne. Next, $c_s(t)$ is the product of the normal catch per vessel of a sub fleet (these are conceptualised as constants being 376, 681, 365, 162, and 244 tonne mixed fish for a small beam trawler, a large beam trawler, an otter trawler, a trammel netter and a shrimp beam trawler, respectively) multiplied by the effect the fish density has on the catch of a vessel. This effect represents a vital part of the dynamic complexity in fisheries following the "law of diminishing returns" as illustrated in Figure 3.15. As a result, and not surprisingly, the lower the fish density, the more difficult it becomes for fishermen to locate fish resulting in catches below the normal levels (Morecroft, 2008).

Figure 3.15: Effect of fish density on catch per vessel



(Source: Own compilation)

In Equation 20, the second bi-flow $I_{fin,s}(t)$ depends on the outcome of the investment decision for sub fleet *s* at time *t*. In the simulation model, this investment decision contains three options: (1) investment in new vessels for sub fleet *s* at time *t* $n_{vessel,buy,s}(t)$, (2) selling vessels of sub fleet *s* at time *t* to agents "outside the scope of the simulation model" (a scrapping company, among others), or (3) decommissioning of vessels of sub fleet *s* at time *t*. However, both last selling options are captured with $n_{vessel,sell,s}(t)$. As a result, $I_{fin,s}(t)$ can be written as:

$$I_{fin,s}(t) = \left(n_{vessel,buy,s}(t)\ \left(P_{vessel,sub,s}(t) - L_s(t)\right)\right) - \left(n_{vessel,sell,s}\left(P_{vessel,old,s}(t) - \frac{D_s(t)}{n_{vessel,s}(t)}\right)\right)\left\{\frac{euro}{year}\right\} \quad (24)$$

Where $L_s(t)$ is the bank loan sub fleet *s* has at time *t* and $P_{vessel,old,s}(t)$ is the price for an old vessel of sub fleet *s* at time *t* which is an output of the sector "investment decision".

Returning to Equation 19, the debts for sub fleet *s* at time *t* is also an asset stock accumulation which accumulates through $ND_s(t)$ being the amount of new debt sub fleet *s* makes at time *t* and drains through $RP_s(t)$ representing the amount of debt which sub fleet *s* repays at time *t*. As a result, $D_s(t)$ at time *t* can now be written as:

$$D_s(t) = D_s(t - dt) + \left(ND_s - RP_{debt,s}\right)dt \quad \{euro\} \quad (25)$$
$$D_{sbt}(0) = D_{sbt}^0 = 10 \quad D_{lbt}(0) = D_{lbt}^0 = 25 \quad D_{ott}(0) = D_{ott}^0 = 10 \quad \{million\ euro\}$$
$$D_{tra}(0) = D_{tra}^0 = 5 \quad D_{shr}(0) = D_{shr}^0 = 7.5 \quad \{million\ euro\}$$

Where D_{sbt}^0, D_{lbt}^0, D_{ott}^0, D_{tra}^0, and D_{shr}^0 are the initial values of the debt for small beam trawlers, large beam trawlers, otter trawlers, trammel netters and shrimp beam trawlers, respectively. These initial values for the debts of the different sub fleets are set equal to the initial values of the savings (see Equation 20). Hence, in the initial phase of the game, this sets the industry value equal to the value of all vessels in the fleet. The designer of the simulation model and the scientific expert group agreed that this is a good initial starting point for playing the game since it allows easy comparison among the different sub fleets.

In Equation 24, the amount of new debts sub fleet *s* makes at time *t* is given by:

$$ND_s(t) = n_{vessel,buy,s}(t)\ L_s(t)\ (1+i) \quad \left\{\frac{euro}{year}\right\} \tag{26}$$

Where i equals the interest of the bank loan which is a constant set at five percent.

Also in Equation 24, the amount of debts sub fleet *s* repays at time *t* is given by:

$$RP_{debt,s}(t) = NRP_{debt,s}(t) + n_{vessel,sell,s} \frac{D_s(t)}{n_{vessel,s}(t)} \quad \left\{\frac{euro}{year}\right\} \tag{27}$$

Returning one last time to Equation 19, the total value of the vessels in sub fleet *s* at time *t* is conceptualised as a "resource attribute" (Sterman, 2000; Warren, 2008) of the number of vessels in the fleet. As a result, $V_s(t)$ is an asset stock accumulation which increases when new value is gained through buying new vessels for sub fleet *s* at time *t* $NV_s(t)$ and decreases through $LV_s(t)$ capturing the loss of value for sub fleet *s* at time *t* through both (1) the aging of the vessels and/or (2) the selling of old vessels. Consequently, $V_s(t)$ at time *t* can be written as:

$$V_s(t) = V_s(t-dt) + (NV_s - LV_s)dt \quad \{euro\} \tag{28}$$
$$V_{sbt}(0) = V_{sbt}^0 = 20 \quad V_{lbt}(0) = V_{lbt}^0 = 50 \quad V_{ott}(0) = V_{ott}^0 = 20 \quad \{million\ euro\}$$
$$V_{tra}(0) = V_{tra}^0 = 10 \quad V_{shr}(0) = V_{shr}^0 = 15 \quad \{million\ euro\}$$

Where V_{sbt}^0, V_{lbt}^0, V_{ott}^0, V_{tra}^0, and V_{shr}^0 are the initial values of the debts for small beam trawlers, large beam trawlers, otter trawlers, trammel netters and shrimp beam trawlers, respectively, which the scientific expert group set to be double the value of $S_s(t)$ and $D_s(t)$.

In Equation 28, $NV_s(t)$ at time *t* is:

$$NV_s(t) = n_{vessel,buy,s}(t)\ P_{vessel,new,s}(t) \quad \left\{\frac{euro}{year}\right\} \tag{29}$$

And also in Equation 28, $LV_s(t)$ at time *t* is given by:

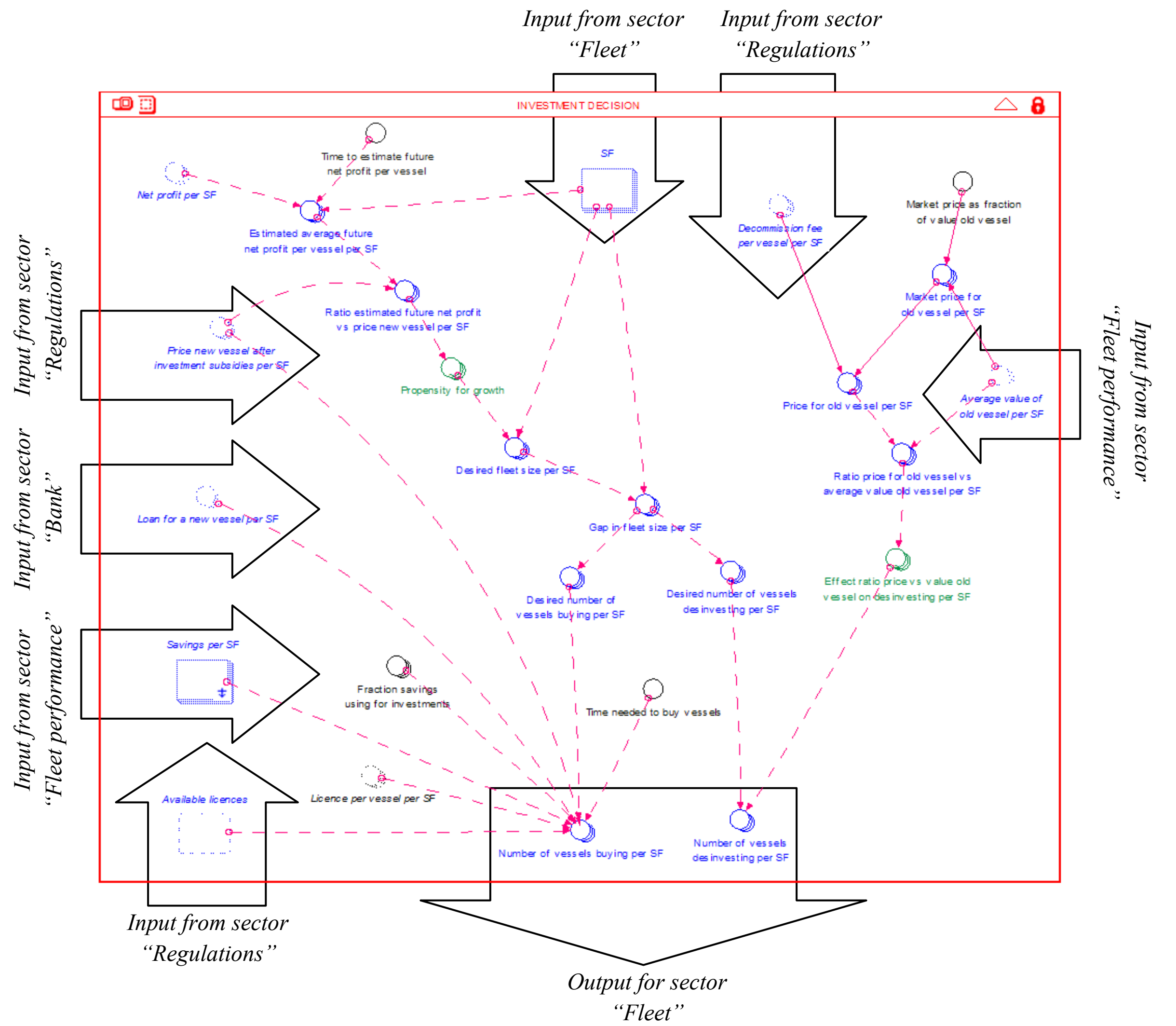
$$LV_s(t) = LV_{aging,s}(t) + \left(n_{vessel,sell,s}(t) \frac{V_s(t)}{n_{vessel,s}(t)}\right) \quad \left\{\frac{euro}{year}\right\} \tag{30}$$

Where $LV_{aging,s}(t)$ is the value lost through aging conceptualised as $V_s(t)$ divided by the average life span of a vessel. In order to simplify the model, this simulation model sets the life span of a vessel equal to the debt repayment period of the debts originally made when buying the vessel. Hence, the lifespan of the vessels equals the debt repayment period, which are both set constant at 20 years.

SECTOR 5: INVESTMENT DECISION

The SFD of this sector on investment decision is given in Figure 3.16.

Figure 3.16: Stock and flow diagram capturing the sector of investment decision with its in-flows from and out-flows to the other sectors (“SF” = “Sub Fleet”)



(Source: Own compilation)

As stated earlier, the investment decision contains three options: (1) $n_{vessel,buy,s}(t)$, (2) $n_{vessel,sell,s}(t)$ to agents “outside the scope of the simulation model” (e.g., scrapping company among others), or (3) $n_{vessel,sell,s}(t)$ through decommissioning. The investment in new vessels for sub fleet s at time t is given by:

$$n_{vessel,buy,s}(t) = \frac{max\left(min\left(min\left(\frac{sa_s\, S_s(t)}{P_{vessel,sub,s}(t) - L_s(t)}, n_{vessel,buy,s}^{desired}(t)\right), \frac{n_{lic}(t)}{n_{lic,vessel,s}}\right), 0\right)}{t_{vessel,buy}} \quad \left\{\frac{vessel}{year}\right\} \tag{31}$$

Where sa_s is the fraction of the savings sub fleet s uses for investments at time t which is set constant at 80%, $n^{desired}_{vessel,buy,s}$ is the desired number of vessels sub fleet s wants to buy at time t, and $t_{vessel,buy}$ is the time needed to buy the vessels at time t which is a constant set at one year.

In Equation 30, the desired number of vessels sub fleet s wants to buy at time t is

$$n^{desired}_{vessel,buy,s}(t) = max\left(n^{desired}_{vessel,s}(t) - n_{vessel,s}(t), 0\right) \quad \{vessel\} \tag{32}$$

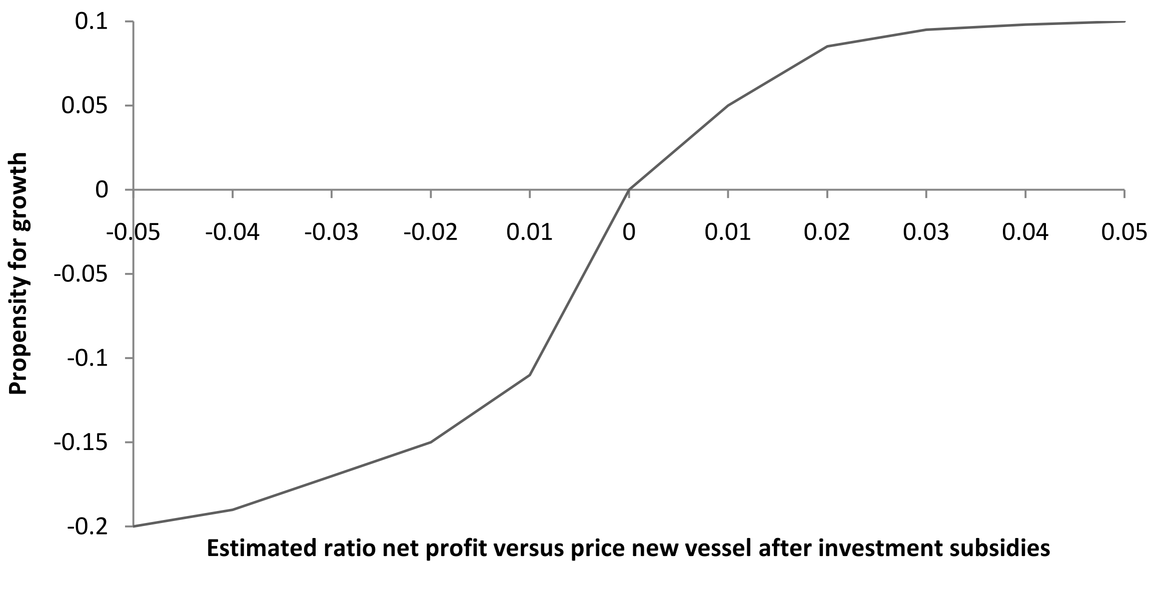
Where $n^{desired}_{vessel,s}$ is the desired number of vessels sub fleet s wants to have at time t. This equation determines if there is a positive gap between $n^{desired}_{vessel,s}(t)$ and $n_{vessel,s}(t)$ and defines it as the desired number of vessels sub fleet s wants to buy at time t. Defining such gaps between desired and actual states of the system are very important in system dynamic models since they drive important actions in these simulation models.

To obtain the positive gap between $n^{desired}_{vessel,s}(t)$ and $n_{vessel,s}(t)$ in Equation 32, the desired number of vessels for sub fleet s at time t needs to be determined. Since the desired value of a variable is always based on the current state, $n^{desired}_{vessel,s}(t)$ can be written as:

$$n^{desired}_{vessel,s}(t) = n_{vessel,s}(t)\left(1 + Gr_s(t)\right) \quad \{vessel\} \tag{33}$$

Where $Gr_s(t)$ is called "the propensity for growth" for sub fleet s at time t. This concept is borrowed from Morecroft's (2008; 2007) "fish and ships"-microworld and is conceptualised as a graphical function (Figure 3.17).

Figure 3.17: Propensity for growth given the estimated ratio of net profit versus the price for a new vessel after investment subsidies



(Source: Own compilation)

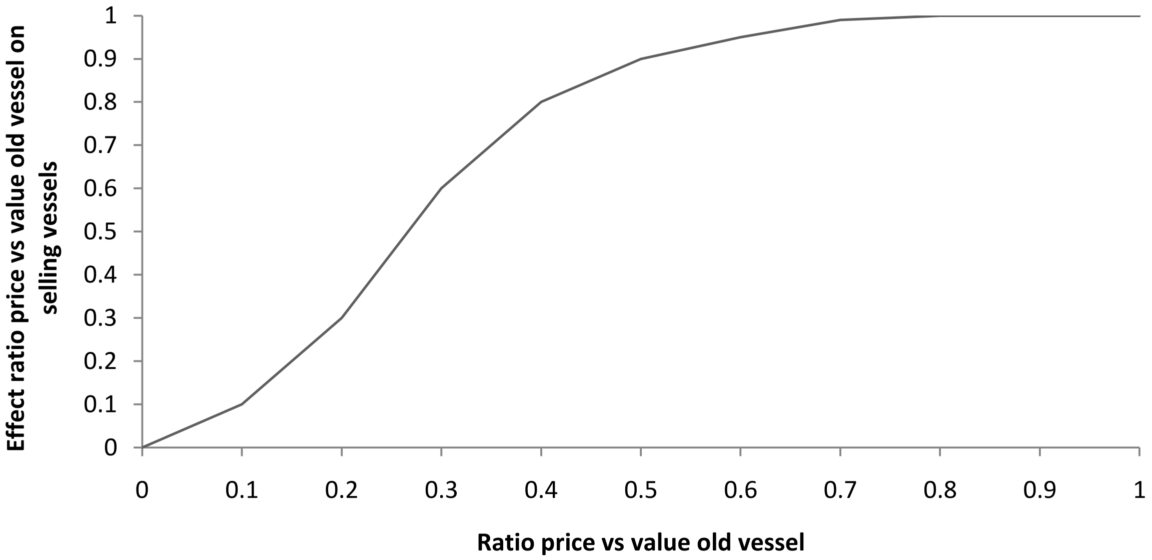
In this figure, the estimated ratio of net profits versus the price of a new vessel after investment subsidies is calculated as the estimated average future net profits for a vessel of sub fleet s at time t $\widehat{\overline{np}}_{vessel,s}(t)$ divided by $P_{vessel,sub,s}(t)$. Finally, $\widehat{\overline{np}}_{vessel,s}(t)$ is the result of $NP_s(t)$ divided by $n_{vessel,s}(t)$ subject to a first-order smoothing over the time needed to estimate and adjust the future net profits for each new *t* (which is set at one year).

A second option for each sub fleet in the investment decision is to sell their vessels. This decision $n_{vessel,sell,s}(t)$ at time *t* can be written as:

$$n_{vessel,sell,s}(t) = n^{desired}_{vessel,sell,s}(t)\ E_{\frac{P_{vessel,old}}{\bar{V}_{vessel}},s}(t) \quad \left\{\frac{vessel}{year}\right\} \tag{34}$$

Where $n^{desired}_{vessel,sell,s}(t)$ is the desired number of vessels sub fleet s wants to sell at time *t* and $E_{\frac{P_{vessel,old}}{\bar{V}_{vessel}},s}(t)$ is the nonlinear effect the ratio of $P_{vessel,old,s}(t)$ over the maximum between $\bar{v}_{vessel,s}(t)$, being the average value of an old vessel of sub fleet *s* at time *t*, and one has on $n_{vessel,sell,s}(t)$. This effect is conceptualised in this simulation model as the graphical function given in Figure 3.18.

Figure 3.18: Effect of ratio price versus value of an old vessel on selling vessels



(Source: Own compilation)

Next, the price for an old vessel of sub fleet *s* at time *t* is

$$P_{vessel,old,s}(t) = max\left(P_{vessel,dec,s}(t), P_{vessel,sell,s}(t)\right) \quad \left\{\frac{euro}{vessel}\right\} \tag{35}$$

Where $P_{vessel,sell,s}(t)$ is the price for an old vessel of sub fleet s at time *t* when selling it to agents "outside the scope of the simulation model". The obvious underlying idea of this

equation is that fishermen will choose between decommissioning and selling based which option results in the highest price for their old vessels.
Recalling Equation 12, where $P_{vessel,dec,s}(t)$ was conceptualised as a fraction of the average value of an old vessel of sub fleet s at time t which policymakers are willing to pay for given their target of reducing overcapacity, $P_{vessel,sell,s}(t)$ is conceptualised similarly. As a result, $P_{vessel,sell,s}(t)$ at time t is

$$P_{vessel,sell,s}(t) = m\frac{V_s(t)}{n_{vessel,s}(t)} \quad \left\{\frac{euro}{vessel}\right\} \tag{36}$$

Where m is the fraction of the average value of a vessel of sub fleet s at time t at which the market is willing to buy old vessels of the Belgian fleet. m is set constant at 0.25.

In Equation 33, the desired number of vessels sub fleet s wants to sell at time t is obtained similarly as $n^{desired}_{vessel,buy,s}$(t) (see Equation 32) and can be written as

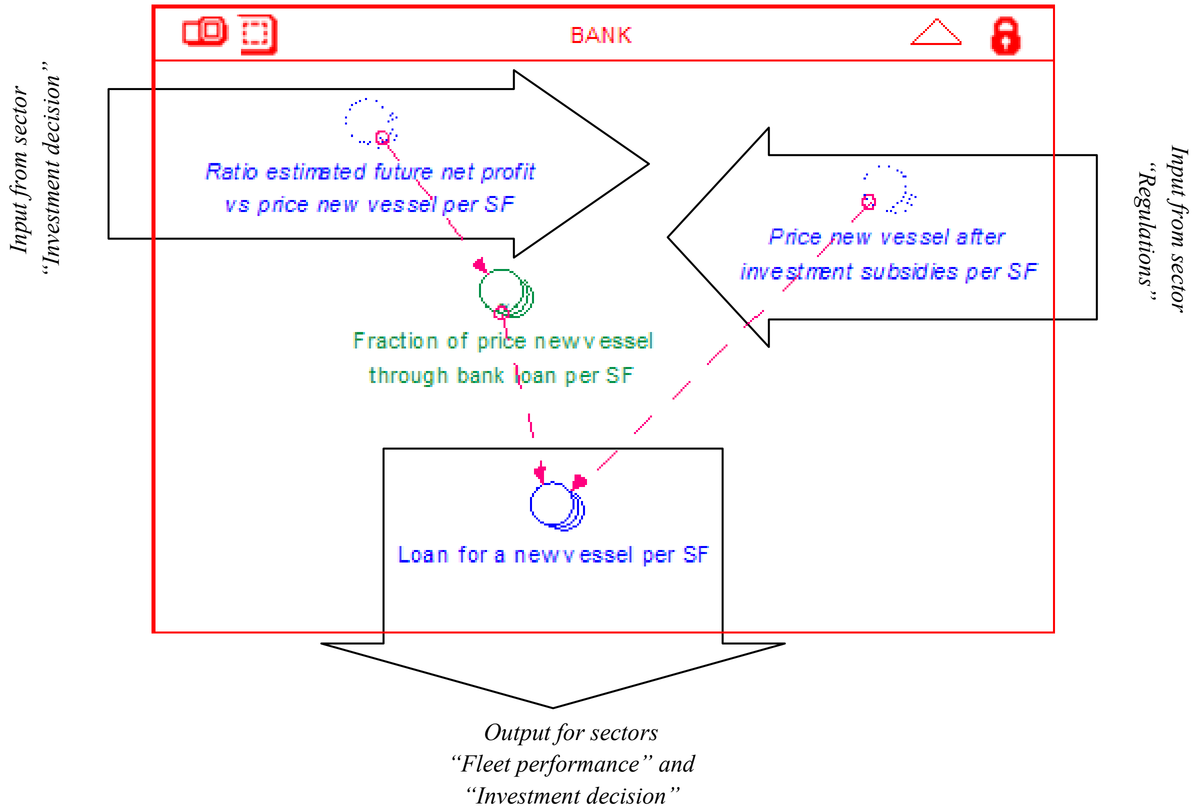
$$n^{desired}_{vessel,sell,s}(t) = -min\left(n^{desired}_{vessel,s}(t) - n_{vessel,s}(t), 0\right) \quad \{vessel\} \tag{37}$$

This equation determines if there is a negative gap between $n^{desired}_{vessel,s}(t)$ and $n_{vessel,s}(t)$ and defines it as the desired number of vessels sub fleet s wants to sell at time t.

SECTOR 6: BANK SECTOR

Figure 3.19 is the SFD containing the basic mechanism of how financial institutions (i.e., banks) determine the level of $L_s(t)$ at time t. Bank loans are common in fisheries given the high price of new vessels. As a result, the role of banks cannot be omitted from the simulation model since growth or decline of a fishing industry often depends on their so-called generosity.

Figure 3.19: Stock and flow diagram capturing the bank sector with its in-flows from and out-flow to the other sectors (“SF” = “Sub Fleet”)



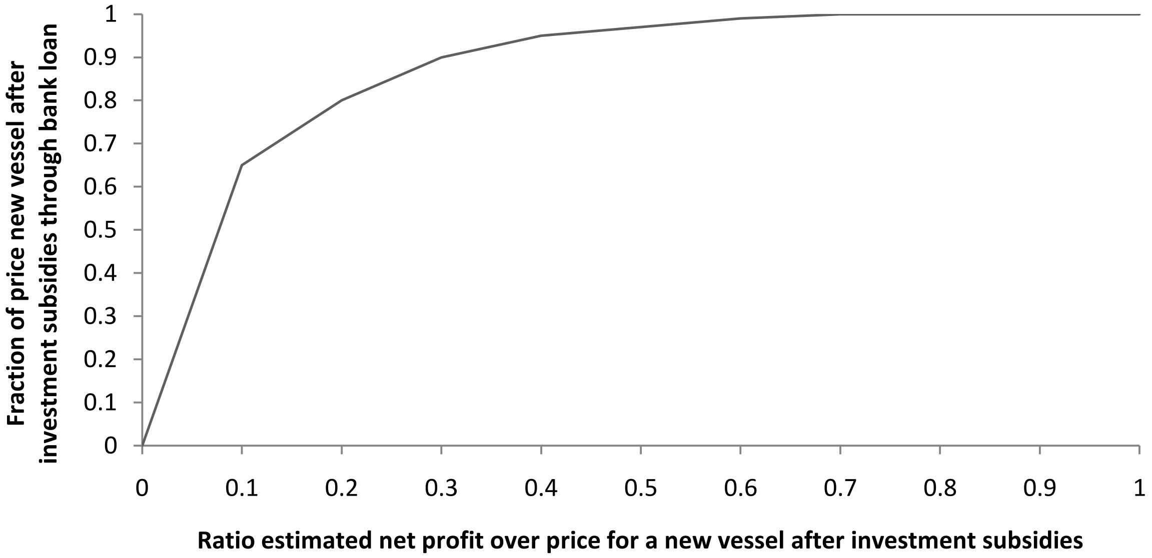
(Source: Own compilation)

The scientific expert group agreed that banks grant loans based on the estimated financial performance (as a simplification of a firm’s debt repayment capacity; see above) of the firm (i.e., vessel) requesting the loan. Consequently, $L_s(t)$ for sub fleet *s* at time *t* can be written as:

$$L_s(t) = l(t)\, P_{vessel,sub,s}(t) \quad \left\{\frac{euro}{vessel}\right\} \tag{38}$$

Where $l(t)$ is the fraction of the price of a new vessel after investment subsidies the bank is willing to lend at time *t*. This simulation model uses a graph function to conceptualise $l(t)$ (Figure 3.20).

Figure 3.20: Fraction of price new vessel after investment subsidies through bank loan

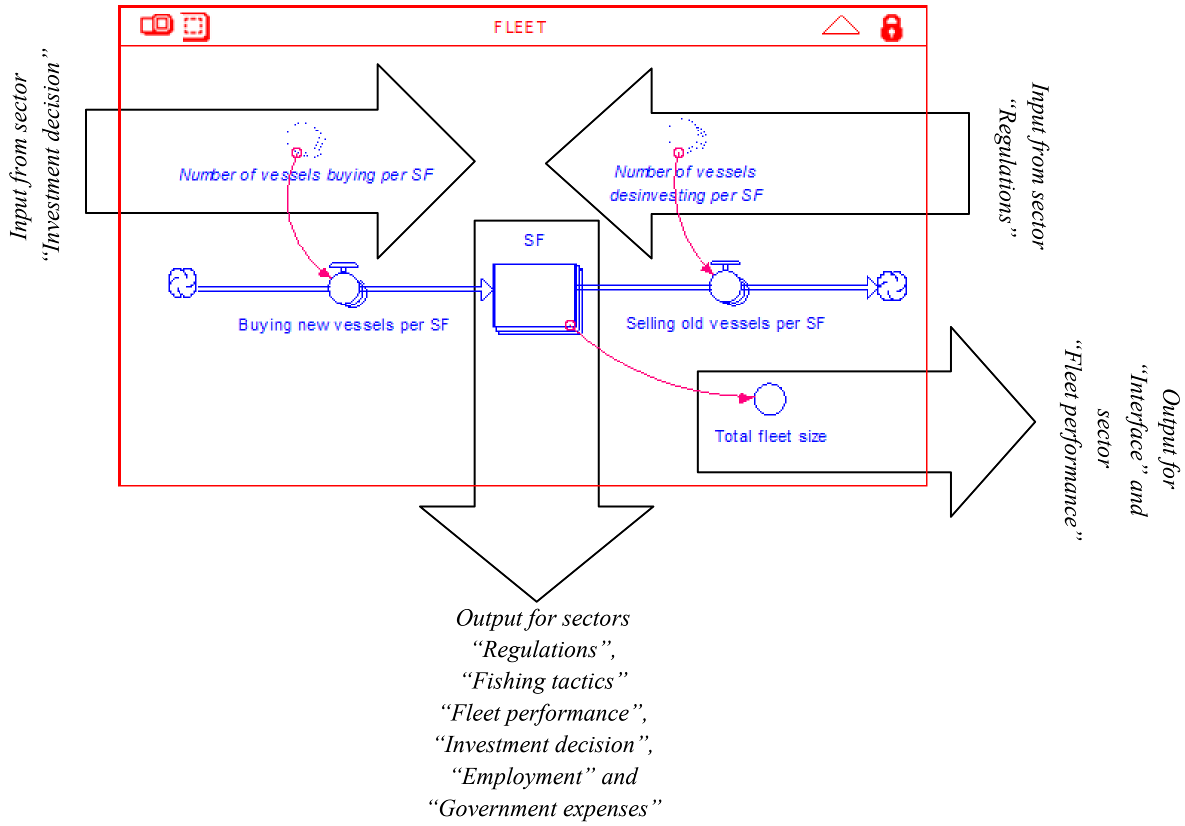


(Source: Own compilation)

SECTOR 7: FLEET

Figure 3.21 illustrates the SFD for the sector capturing the fleet dynamics.

Figure 3.21: Stock and flow diagram capturing the fleet with its in-flows from and out-flows to the other sectors ("SF" = "Sub Fleet")



(Source: Own compilation)

Consequently, the number of vessels in the fleet at time *t* is given by

$$n_{vessel}(t) = \sum_{s} n_{vessel,s}(t) \quad \{vessel\} \tag{39}$$

In Equation 39, $n_{vessel,s}(t)$ are represented by asset stock accumulations used to track the behaviour of the fleet sizes of the five sub fleets through time. These stocks increase through the inflow of purchased new vessels and decrease through the outflow of selling old vessels. Consequently, both flow rates are a result of the endogenous defined investment decisions of the ship owners (see sector "investment decision"). Therefore, $n_{vessel,s}(t)$ at time *t* can be written as:

$$n_{vessel,s}(t) = n_{vessel,s}(t-dt) + \left(n_{vessel,buy,s} - n_{vessel,sell,s}\right)dt \quad \{vessel\} \tag{40}$$
$$n_{vessel,s}(0) = n^{0}_{vessel,s} = 25 \quad \{vessel\}$$

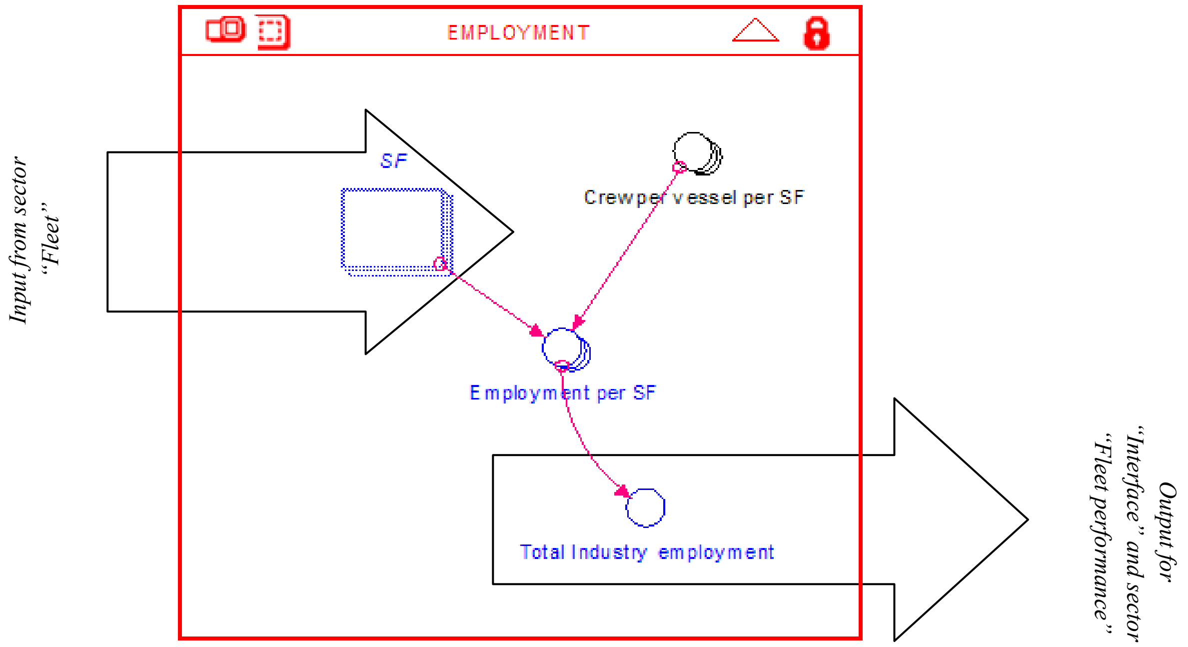
This equation illustrates that the initial values of the number of vessels for each of the sub fleets is set at 25. Although this does not reflect the real situation in Belgian fisheries, the scientific expert group agreed that the initial condition for playing the microworld base on this simulation model should be one where all sub fleets start with the same number of vessels.

Twenty-five was chosen to create a total fleet of 125 vessels, roughly the average total fleet size of the Belgian fleet between 1997-2006.

SECTOR 8: EMPLOYMENT

Figure 3.22 illustrates the SFD for this sector on employment.

Figure 3.22: Stock and flow diagram capturing employment with its in-flow from and out-flow to the other sectors (“SF” = “Sub Fleet”)



(Source: Own compilation)

Hence, total employment of the fleet at time t $n_{person}(t)$ is given by:

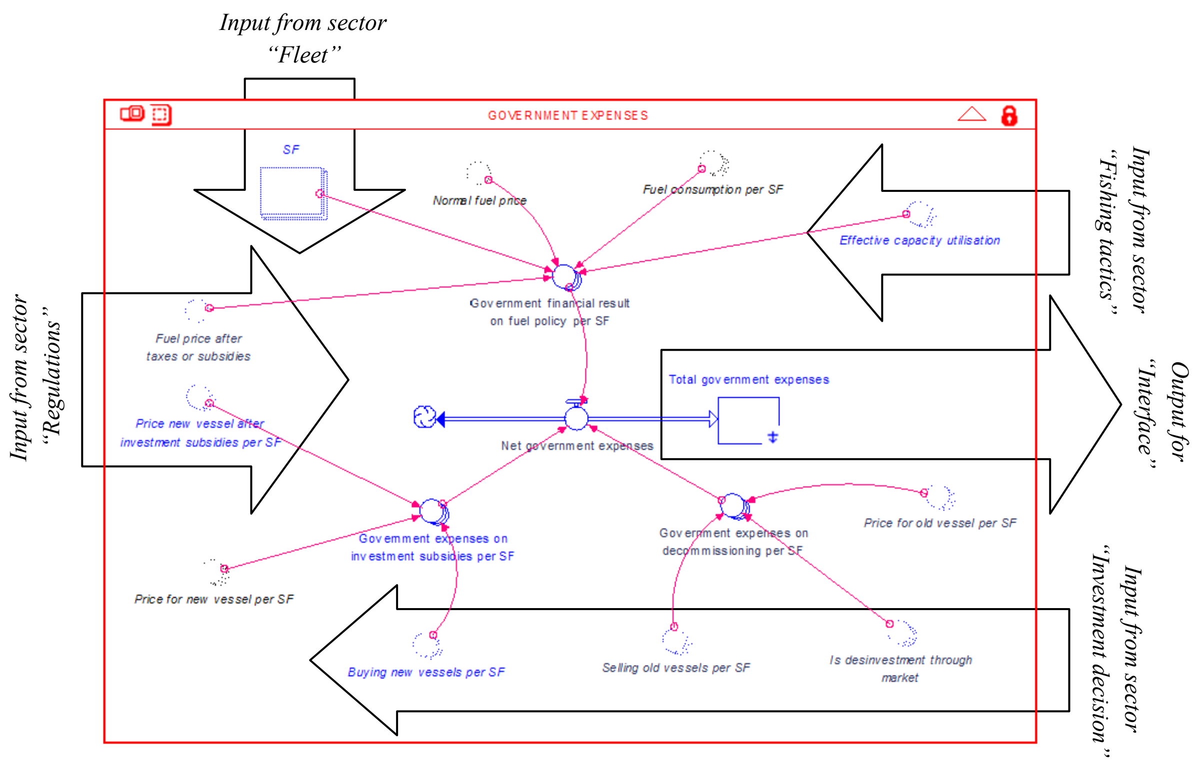
$$n_{person}(t) = \sum_{s} n_{person,s}(t) \quad \{person\} \tag{41}$$

Where $n_{person,s}(t)$ is the total employment for sub fleet s at time t which is $n_{vessel,s}(t)$ times the average crew per vessel for sub fleet s at time t. In this simulation model, the average crew per vessel for the different sub fleets are constants, with their values set to the average of the strictly regulated (KB, 1973: art 94) minimum number of required crew members. This number differs among sub fleets. This option was chosen because data on the number of crew members are nearly impossible to collect; they are not stored electronically and many media (often volatile) have been used to inform authorities about the number of persons on board (e.g., fax, phone, email and mobile text message). As a result, average number of crew members per vessel are set to three persons for small beam trawlers, otter trawlers and trammel netters; five persons for large beam trawlers; and two persons for shrimp beam trawlers (KB, 1973: art 94).

SECTOR 9: GOVERNMENT EXPENSES

Implementing (1) fuel taxes or subsidies, (2) investment subsidies, and/or (3) decommission fees result in the government making or spending money. As a result, tracking these expenses is also important in the simulation model since these expenses are paid for by the Belgian taxpayers.
Figure 3.23 illustrates the SFD on how this sector is conceptualised.

Figure 3.23: Stock and flow diagram capturing the government expenses with its in-flows from and out-flow to the other sectors ("SF" = "Sub Fleet")



(Source: Own compilation)

In this SFD, the total government expenses at time t $G(t)$ is conceptualised as an asset stock accumulation which accumulates or drains through its only bi-flow $NG(t)$ being net government expenses at time t. As a result, $G(t)$ at time t can be written as:

$$G(t) = G(t - dt) + (NG)dt \quad \{euro\} \qquad (42)$$
$$G(0) = G^0 = 0 \quad \{euro\}$$

Obviously, the initial value for the total government expenses is set to zero.

In Equation 42, net government expenses at time t is given by:

$$NG(t) = \sum_s G_{fuel,s}(t) + \sum_s G_{Isub,s}(t) + \sum_s G_{Idec,s}(t) \quad \left\{\frac{euro}{year}\right\} \tag{43}$$

Where $G_{fuel,s}(t)$ is the financial result for the government for its chosen fuel policy at time *t* whereas $G_{Isub,s}(t)$ and $G_{Idec,s}(t)$ are the government expenses made at time *t* by granting investment subsidies and decommission fees, respectively.

In Equation 43, the financial result for the government on the chosen fuel policy at time *t* is

$$G_{fuel,s}(t) = U_s(t)\, n_{fuel,vessel,s}\, n_{vessel,s}(t) \left(P_{fuel}(t) - P_{fuel,reg}(t)\right) \quad \left\{\frac{euro}{year}\right\} \tag{44}$$

In Equation 43, the government expenses on investment subsidies at time *t* are

$$G_{Isub,s}(t) = n_{vessel,buy,s}(t) \left(P_{vessel,new,s} - P_{vessel,sub,s}(t)\right) \quad \left\{\frac{euro}{year}\right\} \tag{45}$$

Also in Equation 43, the government expenses on decommission fees at time *t* are

$$G_{Idec,s}(t) = if\,(Y_s(t) = 1)\ then(0)\ else\left(n_{vessel,sell,s}(t)\, P_{vessel,old,s}(t)\right) \quad \left\{\frac{euro}{year}\right\} \tag{46}$$

3.3.4 Testing

After the simulation model is developed, the next step in the modelling process is testing. In this study, many of the tests were undertaken in the different scientific expert group meetings. In addition, the final microworld was also presented and discussed in a scientific expert group meeting fully dedicated to testing the microworld. In these meetings, the microworld passed on (1) boundary adequacy tests, (2) structure verification tests, (3) parameter verification tests, and (4) qualitative tests of fit (see Appendix 1 for the main qualitative tests of fit). Next, the dimensional consistency test was performed and no errors occurred. Finally, many extreme condition scenarios were launched into the microworld all resulting in plausible and satisfying outcomes.

3.3.5 The microworld: the game and user friendly interface

This microworld that locks the dynamic simulation model is based on a game run in a dynamic decision making mode in which players of the game are invited to alter policy instruments annually through switches and sliders in an attempt to maximise their votes for the upcoming elections (see Appendix 2 for the interface of this microworld). Hence, through yearly alteration of sliders, players of the game demonstrate their policy strategy for that fisheries system to the different stakeholder groups involved. This collective group of stakeholders will then vote in function of how well the player paid attention to their needs as captured by (1) total industry value $V_{ind}(t)$, (2) industry value per vessel $\frac{V_{ind}(t)}{n_{vessel}(t)}$, (3) fleet size $n_{vessel}(t)$, (4) industry employment $n_{person}(t)$, (5) average wages $\frac{n_{person}(t)}{n_{vessel}(t)}$, (6) government expenses $G(t)$, and (7) estimated fish stock $\hat{B}(t)$. This voting system is effectively a weighting on the importance of these objectives. The player's score on each of these objectives is indicated on the interface by "status lamps"; where a green light means "doing very well" so the player gains 20000 votes, yellow light means "can do better", but the players still gains 10000 votes and red means "highly neglecting this objective" and the player loses 30000 votes (weights are made up for the purpose of the excercise). Table 3.2 illustrates the range for the colour codes of the status lamps for all of the seven objectives. As a result, the change in colours occurs when thresholds are crossed. The total amount of votes a player has acquired is then simply the sum of the votes for each of these seven objectives. Finally, the more votes the player has obtained, the better the score and so the higher the chance of becoming re-elected.

Table 3.2: Range for the colour codes of the status lamps for all of the seven management objectives included in the microworld

	Status lamps colour range		
	Red	Yellow	Green
Total industry value	0 - 3e08	3e08 - 5e08	5e08 - ∞
Industry value per vessel	0 - 2e06	2e06 - 4e06	4e06 - ∞
Fleet size	0 - 100	100 - 150	150 - ∞
Industry employment	0 - 300	300 - 500	500 - ∞
Average wages	0 - 40000	40000 - 70000	70000 - ∞
Government expenses	6e07 - ∞	3e07 - 6e07	0 - 3e07
Estimated fish stock	0 - 36000	36000 - 60000	60000 - 80000

(Source: Own compilation)

Next, the player can use a variety of policy options to formulate a policy strategy (see stock and flow diagram "regulation" above). First, $Q(t)$ can be set by varying $pj^{desired}(t)$ between -0.5 and 0.5 by means of a slider. As a result, the player is in the microworld free to decrease or increase $Q_r(t)$ by 50 percent. Second, the player can decide which proportion of $Q(t)$ is allocated to each sub fleet by altering $pq_s^{desired}(t)$ for each sub fleet through the use of five sliders. The player is free to vary $pq_s^{desired}(t)$ between zero and ten, keeping in mind that altering one of them affects all others. Third, the player can choose to set the desired number of fishing days for each of the sub fleets (0-365 days). Obviously, this is done through five independent sliders. Fourth, a switch can be handled by the gamer to implement catch restrictions per fishing day or not (i.e., the boolean $Z(t)$). Fifth, the player can control the number of available licences through $n_{lic,reg}(t)$ which is a slider able to vary between minus ten and ten. However, when choosing a negative value for $n_{lic,reg}(t)$, this only decreases the available licences not yet used by fishermen. Consequently, a negative value will not force vessels to leave the fleet. Sixth, the player can alter, though a slider, $df_s^{desired}(t)$ between zero and one to set the amount of the decommissioning fee for the different sub fleets as a desired proportion of the average value of a vessel of these sub fleets. Seventh, the player can also decide to vary $is_s^{desired}(t)$ by means of a slider, altering the amount of investment subsidies given (in the form of a fraction of the price of a new vessel) when ship owners buy new vessels. Finally, the player's last option is to alter through a slider $f(t)$ between -0.5 and 0.5 resulting in fuel subsidies and taxes, respectively.

3.4 Discussion

This study has developed a microworld (i.e. (simple) dynamic simulation model with user-friendly gaming interface) in which stakeholders can "play" and gain long-term insights into the effect policy instruments have on the Belgian fisheries system. Such a tool is helpful since managing fisheries systems is difficult and often results in unsustainable fisheries where fish stocks collapse, industry profits evaporate and dissatisfaction with the management system grows. This microworld can answer these problems however, it is necessary to be clear about what to expect when using it. Clearly, it can be used as a learning laboratory for ex ante evaluation of possible policy strategies (De Geus, 1997; Keys *et al.*, 1996). However, it is no fortune teller. Its purpose is not forecasting, prediction or optimisation (Morecroft, 1999). What it does offer is a risk-free environment in which policy strategies can be evaluated much faster than in the real world because delays in the learning process are drastically reduced (De Geus, 1997; Sterman, 2000). In addition, a microworld not only enhances the speed, but also improves the quality of that learning process since such a risk-free environment allows more room for creativity, imagination, adventure and fantasy (Stouten *et al.*, 2007a). Finally, this microworld can also be used as a transitional object in which strategies are rehearsed and visualised (Morecroft, 1999) bringing them into debate and discussion (Morecroft, 1984) among stakeholder groups. As a result, policymakers will be able to better illustrate and discuss the implications of different policy strategies among themselves and other stakeholder groups. Hence, these other stakeholder groups will see more clearly the difficulties encountered when managing fisheries systems. This can lead to a better mutual understanding among the stakeholder groups of the fisheries management problems resulting in changing (1) knowledge, (2) attitudes, and (3) behaviour toward policy instruments and management systems.

However, these benefits rely on the stakeholders' confidence in the microworld. They need to believe that the dynamic simulation model underlying the microworld resembles the real world situation. Nevertheless, they often start to criticise the simulation model and start questioning its scope and underlying assumptions. This problem of face-validity is almost impossible to rule out completely since "all models are wrong" (Sterman, 2002) and their limitations depend mainly on the mental model (i.e., a person's "deeply held internal images of how the world works" (Senge, 1990: 174)) through which one is looking at the simulation model. Therefore, developing a simulation model unavoidably results in discussions and uncertainties related to its scope and underlying assumptions. A first and important discussion in the development of our simulation model was related to the inclusion of arrays in the simulation model (e.g., sub fleets, fishing grounds and species). It was clearly tempting for the scientific expert group to disaggregate stocks simply because it made the simulation model look more like the real system. The scientific expert group, being scientists striving for accuracy, found it difficult to abandon this form of "detailed complexity" (Senge, 1990). The scientific expert group was only willing to reduce the number of arrays to one (the five sub fleets) once they were shown that detailed complexity can blur or block our understanding of "dynamic complexity" (Senge, 1990) and explained the two rules for disaggregation of stocks (Richardson *et al.*, 1999). As a result, the scientific expert group agreed that this array was required in order for the simulation model to be able to address relevant management issues such as choosing between a diverse or (re)focused fleet. The added complexity given by including other arrays (e.g., fishing grounds or species) could not be justified and were thus left out of the simulation model.

A second point of discussion was the absence of market dynamics in the simulation model, especially for setting fish prices. Fish prices are in this case conceptualised as constants varying among the sub fleets reflecting differences in "quality" (i.e., catch composition, size of the fish, freshness, injuries, etc.) of their landed fish. Some experts initially saw the absence of a market mechanism influencing the fish price as an important shortcoming and commented that including such a mechanism is not too demanding and would better reflect reality. However, this was rebutted since Belgium is a small player on the fish market (i.e., Belgium market is only 0.48% of European market in 2010 (EC, 2010)), meaning that Belgian demand and supply has no strong effect on fish prices, and results in Belgium being a price taker. In addition, including a realistic market mechanism for fish prices should have to incorporate the effect of import and export, and aquaculture, especially since the latter strongly affects fish prices (Anderson, 2007). Such a market mechanism would have significantly expanded the scope of the simulation model. The scientific expert group decided that the market dynamics were not necessary given that the focus of this study is on learning about the effect policy instruments have on Belgian fisheries.

A third discussion was related the omission of the ecological aspect of fisheries and its indirect economic effects. First of all, this study sets catch equal to landings and thus excludes the whole discard problem (e.g., Davies *et al.*, 2009; Kelleher, 2005) together with its economic impact. Discards are a waste of natural resources affecting the marine ecosystem (Hall, 1994; Kelleher, 2005) resulting in the loss of potential income (and human food sources) (Catchpole *et al.*, 2005). In addition to discards, fishing also impacts the bottom habitat (e.g., Chuenpagdee *et al.*, 2003; Kaiser *et al.*, 2006; Rice, 2006; Watling *et al.*, 1998) which decreases carrying capacity (Dudley, 2008). Therefore, in reality, damage to carrying capacity is cumulative and is proportional to the amount of fishing taking place (Dudley, 2008). However, this disruptive effect of fishing on carrying capacity is not taken into account in the simulation model since the carrying capacity ($B^{max}(t)$) is set as a constant. This could become an interesting topic for improving the simulation model and further research. Inspiration on how to conceptualise this can be found in Dudley (2008).

A fourth discussion point is related to the "catchability" of the vessels in the simulation model. Where in the simulation model the catch per vessel of the different sub fleet only depends on the fish density of the fish stock, another important aspect is the evolution of the efficiency of fishing gear. Obviously, when catch per unit of effort (in this simulation model: catch per time step) drops significantly, the fishers who remain will attempt to improve the efficiency of their fishing gear through maintenance or innovations (Dudley, 2008). This limitation was perceived by some experts in the scientific expert group as an important limitation to the simulation model. However, after having further discussed this topic in the group, these experts came to realise that this simulation model implicitly assumes that a constant yearly maintenance cost (a component of the fixed costs) in combination with yearly fishing gear costs (a component of the variable costs) keeps "catchability" constant. The scientific expert group agreed that this simple assumption contains a satisfying degree of reality. In addition, these experts also know that innovative technical improvement of fishing gear is a very slow process. Hence, this is an example where "a quantity is modelled as a constant not because it never changes, but because in the timeframe of the model it essentially does not change" (Richardson *et al.*, 1999: 186).

In addition to these discussions on the scope, conceptualisation and underlying assumptions of the simulation model, two other important discussions were held. The first one relates to the way in which the scientific expert group meetings were used to develop the simulation model. Since this study had limited resources, these scientific expert group meetings where not held according to rigid guidelines (i.e., scripts) in group model building (Andersen *et al.*, 1997). For instance, this study did not follow the guideline on having a team of (1) facilitator/elicitor, (2) modeller/reflector, (3) process coach, (4) recorder, and (5) gatekeeper (Andersen *et al.*, 1997) in addition to the experts in the scientific expert group meetings. The reason for this is simply the lack of human capital. Consequently, this study does not classify as a group model building exercise "pur sang" but rather an iterative process in which the modeller repeatedly called together a group of experts to help (1) conceptualise the simulation model and (2) validate his modelling efforts. Second, there was discussion of some of the roughly estimated parameter values used to run the simulation model, such as the initial value of the total Belgian fish stock (B^0), which was roughly set at 40000 tonne fish. Hence, al lot of time went in discussing the value of such a simulation model based on many rough parameter value estimations. This discussion was solved through illustrating (i.e. running the simulation model under different parameter values) system dynamics' initially rather disturbing fundamental assertion that "the behavior of a system dynamics model is much more a consequence of its structure than its parameter values" (Richardson *et al.*, 1999: 230). In other words, feedback models are relatively insensitive to (small) parameter changes. Therefore, parameters need not be estimated with statistical confidence intervals in order to have confidence in the policy implications of the simulation model. Consequently, a modeller should estimate parameter values only to the degree of accuracy required (Richardson *et al.*, 1999: 230); in this case, this means that it needs to enable learning about the effect policy instruments have on the Belgian fisheries system. However, whatever the parameter type, the system dynamics approach insists that any parameter in the simulation model should have a clear correspondence to a real quantity or concept. In some sense, the quantity should be observable although there are situations in which the term "intuitable" is more appropriate (Richardson *et al.*, 1999).

3.5 Conclusion

This study has developed a microworld (i.e. (simple) dynamic simulation model with user-friendly gaming interface) in which stakeholders can "play" and gain long-term insight into the effect policy instruments have on the Belgian fisheries system. The microworld is a game run in a dynamic decision making mode in which the players are invited to alter policy instruments annually through switches and sliders. Their objective is to maximise their votes for the upcoming elections by gaining the votes of the stakeholders involved in the Belgian fisheries system through demonstrating their policy strategy for that fishing system for the upcoming 20 years. This collective group of stakeholders will then give their votes in function of how well the player paid attention to their needs which are captured by (1) total industry value, (2) industry value per vessel, (3) fleet size, (4) industry employment, (5) average wages, (6) government expenses, and (7) estimated fish stock. The more votes the player obtains, the higher the score and the higher the chance of being re-elected.

The basis for this microworld is a (simple) dynamic simulation model, equipped with a user-friendly interface, that represents the Belgian fisheries system. The chosen modelling methodology is system dynamics because the interactions between policy instruments and the fisheries system contain multiple interlocking feedback loops which can be clearly visually presented by using causal loop diagrams and stock and flow diagrams. As a result, the simulation model is no mathematical black box and can be used as a learning laboratory for ex ante evaluation of possible policy strategies (De Geus, 1997; Keys *et al.*, 1996) since it offers a risk free environment in which policy strategies can be evaluated much faster than in the real world (De Geus, 1997; Sterman, 2000). In addition, it can also be used as a transitional object in which strategies are rehearsed and visualised (Morecroft, 1999) bringing them into debate and discussion (Morecroft, 1984) among stakeholder groups. This can lead to a better mutual understanding among the stakeholder groups of the fisheries management problems resulting in changing (1) knowledge, (2) attitudes, and (3) behaviour toward policy instruments and management systems.

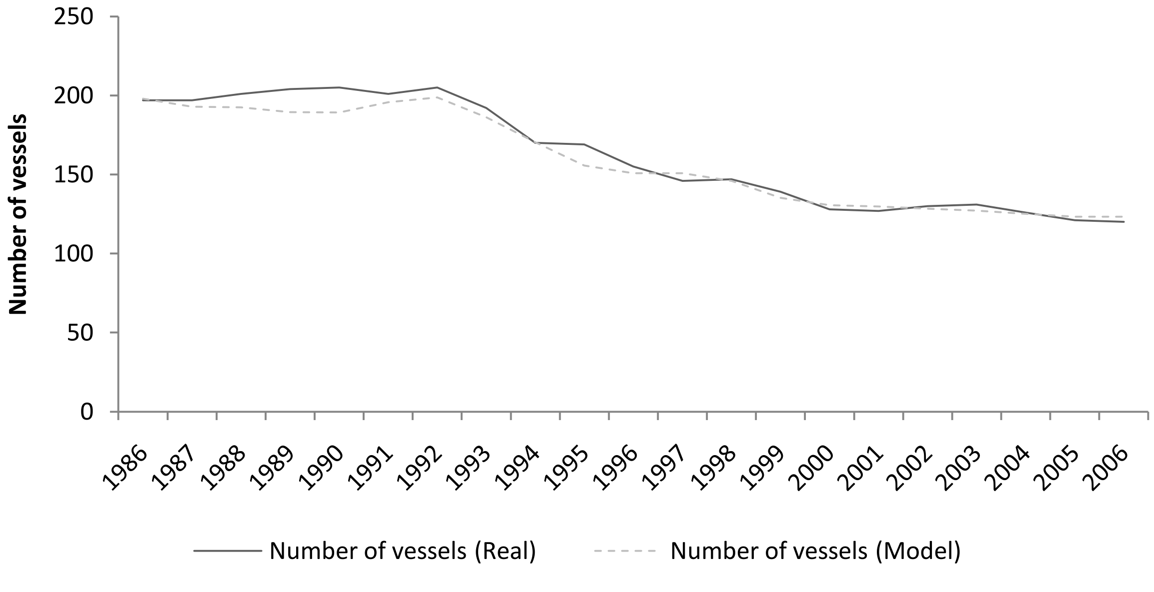
However, for all these benefits to happen, stakeholders playing with the microworld need to have confidence in it. Nevertheless, this problem of face-validity is almost impossible to rule out completely since "all models are wrong" (Sterman, 2002). In this study, four main discussion points where identified related to the conceptualisation of the simulation model underlying the microworld: (1) the limited inclusion of arrays, (2) the absence of any market dynamics, (3) the absence of the ecological aspect of fisheries with its indirect economic effects, and (4) the evolution in fishing gear efficiency. These discussion points form interesting stepping stones for future research.

3.6 Appendix

Appendix 1: Main qualitative tests of fit performed on the dynamic simulation model

This dynamic simulation model originated from the observation that, after having had a stable fleet for almost a decade, a decline in fleet size was setting in around 1992 (see Figure 3.2). As a result, our simulation model should be able to produce this behaviour to a satisfying degree. To investigate if this is the case, this study uses qualitative tests of fit instead of quantitative tests because these formal metrics lose their value when applied to theoretical simulation models which aim at learning. Figure 3.24 shows the fit between the historical data about the fleet size between 1986 and 2006 (as also given in Figure 3.2) and the data generated by our simulation model when run with real trends observed in the Belgian fishing system related to its input variables (e.g., increasing fuel prices, increasing variable and fixed costs, increasing fish prices, decreasing fishing days, slightly decreasing quota, decreasing market value of the vessels, decreasing investment subsidies, catch restrictions per fishing day, two decommissioning rounds and decreasing available licences). It is clear from this figure that the simulation model is able to generate the historical behaviour of the fleet quite successfully. For a start, the stability and slight increase before 1992 is mimicked by the simulated trajectory. Next, the dominant trend of the simulated data after 1992 is a concave decline in fleet size in which periods of decline alternate with periods of stability; just like the real fleet size behaved in this period.

Figure 3.24: Fit between the historical data and the data generated by the simulation model for the total Belgian fleet size (#vessels), 1986 and 2006

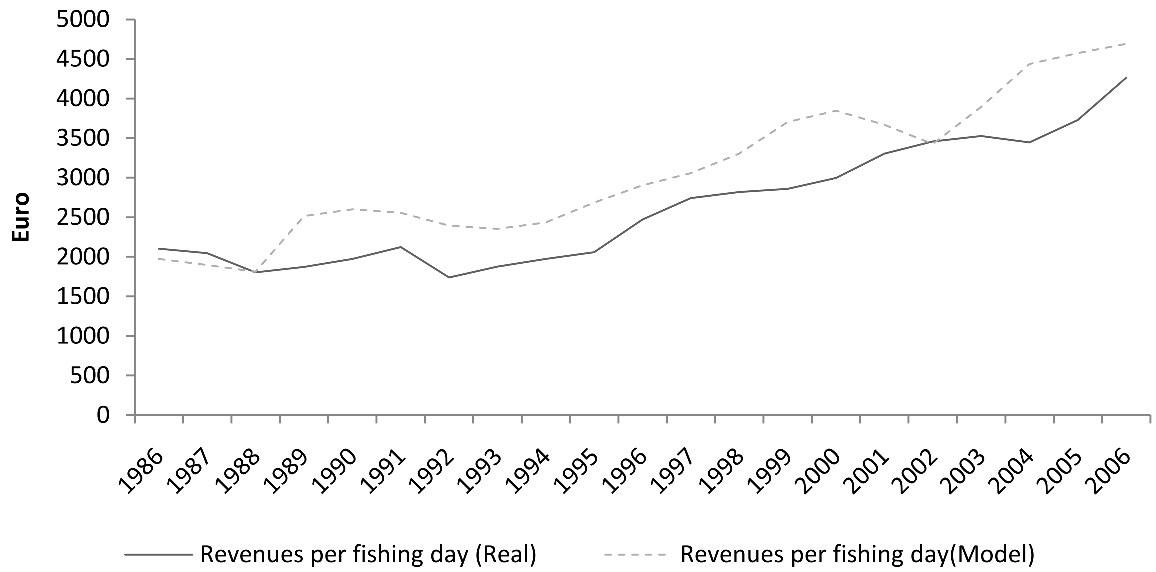


(Source: Own compilation, based on data from the Belgian Sea Fishery Office of the Flemish government)

The simulation model, when run with real trends observed in the Belgian fishing system, also generates realistic trajectories for both revenues (Figure 3.25) and landings (

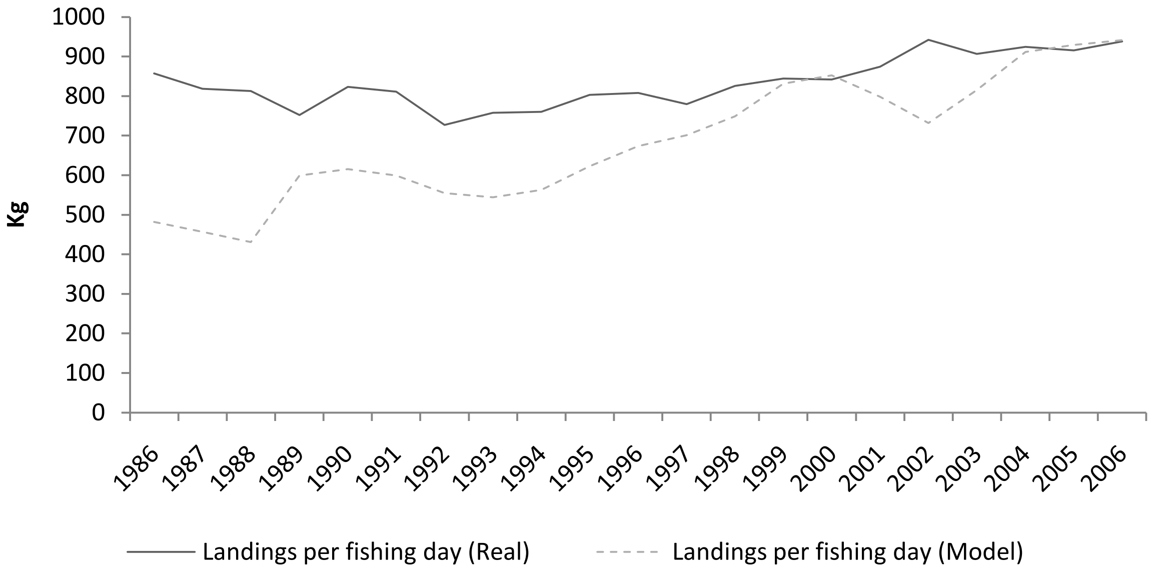
Figure 3.26) per day at sea for an average vessel of the Belgian fleet. Although the fit between the historical data and the data generated by the simulation model for revenues per fishing day is not as good as the fit observed in Figure 3.24, the general trend of steady increase in revenues are similar in both slope and magnitude. The booms and busts in the trajectories also follow roughly similar patterns except for the time period 2000-2004. When looking at the trajectories of landings per fishing day, it is clear that our simulation model is more sensitive to changes in the external environment when compared to the actual behaviour of the historical data. Nevertheless, similar patterns, although amplified, can still be observed between both trajectories. Again with the only exception for the time between 2000-2004 which also partly explains the anomaly observed in Figure 3.25.

Figure 3.25: Fit between the historical data and the data generated by the simulation model for revenues per day at sea of an average vessel of the Belgian fishing fleet (€), 1986 and 2006



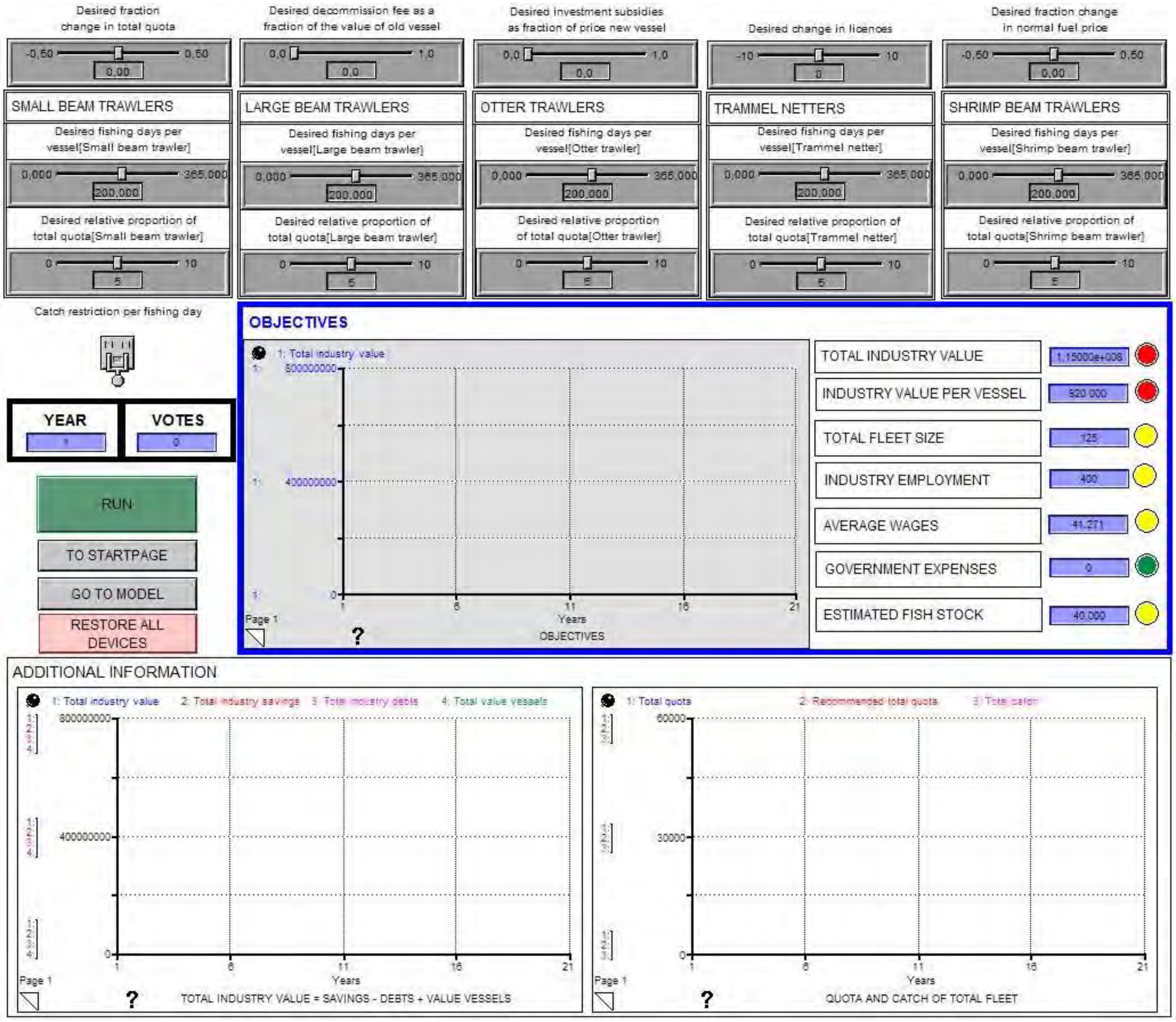
(Source: Own compilation, based on data from the Belgian Sea Fishery Office of the Flemish government)

Figure 3.26: Fit between the historical data and the data generated by the simulation model for landings per day at sea of an average vessel of the Belgian fishing fleet (Kg), 1986 and 2006



(Source: Own compilation, based on data from the Belgian Sea Fishery Office of the Flemish government)

Appendix 2: Interface of the "Belgian Fisheries Microworld"



(Source: Own compilation)

Photo: Policymakers in Belgian fisheries paying attention at a press conference held by ILVO (©Misjel Decleer)

Chapter 4: Policy instruments to meet fisheries management objectives

4.1 Introduction

Since the mid-1990s, between 25 and 30 percent of world fisheries have become seriously overexploited (FAO, 2009b), including those in countries or regions with well-developed fisheries management systems (Dudley, 2008). Overfished species include (1) tuna and other top predator species in international waters (Myers *et al.*, 2003; Sibert *et al.*, 2006; Ward *et al.*, 2005), (2) Canadian cod fisheries (Mason, 2002; Schrank, 2005), and (3) North Sea cod fisheries (Malakoff *et al.*, 2002). Many fisheries worldwide are subject to mismanagement of varying proportions (Arnason, 2009). Fisheries management is very complex (Bjørndal *et al.*, 2004; Pascoe *et al.*, 2009) and fishery managers (i.e., policymakers) must make decisions daily that affect the future of aquatic resources. These decisions are mostly based on the data and information available at that time (Bredehoeft *et al.*, 1993) in combination with some kind of model (Johnson, 1995). This model may be a simple mental model or "rule of thumb", but for more complex situations, decision makers often find it helpful to rely on a formal model such as a computer model. However, the use of computer models is not without danger since their outcomes are frequently interpreted as (exact) quantitative predictions of the future (Morecroft, 1999; Stouten *et al.*, 2007a). Johnson (1995: 745) concludes therefore that "models are often more useful when used as tools to learn more about fisheries and options for management". This approach, looking at computer simulations as learning laboratories, is a perfect fit for this study since this study's objective is to use a microworld to learn more about fisheries systems and the effect fisheries management has on these systems.

Fisheries management can be seen as a problem in multi-objective maximisation (Arnason, 2009; Mardle *et al.*, 2002b). Although many objectives for fisheries management have been suggested (e.g., Charles, 1988; Charles, 2001; Lawson, 1984), they can be broadly classified into four major groups: (1) biological, (2) economic, (3) social and (4) political objectives (Mardle *et al.*, 2002b). The biological objective, commonly found in legislation and international agreements (e.g., Rio Declaration 1992 and Johannesburg Declaration 2002), is the maximisation of biological production, which inherently conserves the fish stocks; this is the traditional idea of maximum sustainable yield (MSY). Economic objectives usually consider economic efficiency or "rent" as the desired outcome of fisheries management, often referred to as maximum economic yield (MEY). Social objectives are mainly employment and income spread among the people of the fishing industry and maintenance of traditional communities, which Hilborn (2007a) terms "maximum job yield" (MJY). Political objectives are primarily related to remaining social peace, namely the avoidance of conflict ranging from violence to lawsuits. This prompted Pope to introduce the concept of MSW: "minimum sustainable whinge" (Pope, 1983). Knowing that not all of these objectives are independent and often conflict with each other (Charles, 1988; Hilborn, 2007a; Jennings, 2007; Mardle *et* *al.*, 2002b), policymakers must agree on the preferred ordering of the importance of these objectives (Afriat, 1967) which results in the definition of an objective function. This objective function is what economists would refer to as a "utility function" or, in the case of a group (or system), a "social welfare function" (Arnason, 2009). This study will refer to an objective function in fisheries management as a social welfare function.

Once a social welfare function is agreed upon, policymakers should adopt a management system that is able to maximise this function (Sutinen, 1998). The chosen social welfare function thus determines the nature of the fisheries management system (Regier *et al.*, 1985). Arnason (2009) broadly classifies fisheries management systems into two classes: (1) biological fisheries management and (2) economic fisheries management. Biological fisheries management (such as gear restrictions, total allowable catches, area closures, nursery ground protection, etc.) is focused on conserving the fish stocks. Economic fisheries management is further divided into (1) direct restrictions and (2) indirect economic management. The difference between these two categories is that direct restrictions (e.g., the effort restriction of limiting the days at sea, fishing time, holding capacity of vessels, engine size, etc.) impose explicit constraints on the activity of the fishermen, while indirect management merely changes the incentives facing the fishermen. Finally, indirect economic management may be divided into two categories; (1) subsidies and taxes and (2) property rights (e.g., fishing licences, sole ownership, territorial use rights, individual quota, and community rights). However, the determination of which of these management systems prevails, as stated above, rests on the policymaker's choice of social welfare function (Regier *et al.*, 1985; Sutinen, 1998). Therefore, this study examines if and how fisheries management systems can be used for completely different social welfare functions. Central to this study is the question "Do policymakers have the policy instruments at hand to align the real fisheries world with their desired social welfare functions?"

We investigated this through different scenarios in Stouten's (2009) microworld called "Belgian Fisheries Microworld". This theoretical microworld is grounded in empirical research about the Belgian fisheries system. It provides a dynamic representation of the changing and interactive relationships between biological, fishing and economic components. It also incorporates behavioural intra-industry responses to policy instruments such as vessel entry/exit decisions and fishing tactics. The objective of the microworld is to give stakeholders room to play, and in the process, gain long-term insights into the effect policy instruments have on the Belgian fisheries system.

These policy instruments impact the fisheries system, and that impact is assessed through the seven potential objectives for fisheries management included in the microworld. They are (1) total industry value (i.e., value of the vessels plus the sum of all savings in the industry minus the sum of all debts in the industry), (2) industry value per vessel, (3) fleet size, (4) industry employment, (5) average wage, (6) total government expenses, and (7) estimated fish stock (i.e., a single species stock that captures the properties of the different species in Belgian fisheries). As a result, this microworld allows the configuration of many objective functions (or social welfare functions) based on different orderings of these potential management objectives.

The fisheries management system is also included in the microworld. Belgium, a member state of the European Union, is bound by the Common Fisheries Policy of the EU (EC, 2002). This Common Fisheries Policy combines the biological and economic management system and is predominantly based on restrictive policy instruments (Mardle *et al.*, 2002b; Stouten *et al.*, 2008). The microworld includes the eight policy instruments that are currently most important for managing the Belgian fisheries system. They are (1) total quota, (2) the allocation of the total quota over the different sub fleets, (3) maximum fishing days, (4) catch restrictions per fishing day, (5) licences, (6) decommissioning fees, (7) investment subsidies, and (8) fuel subsidies and taxes. As a result, this microworld creates conditions for testing whether policymakers can align the real fisheries world (as represented in the microworld) with their desired fisheries world (i.e., the different social welfare functions) through the use of the eight policy instruments included in the microworld. For further information and full details about the development and architecture of Stouten's (2009) "Belgian Fisheries Microworld", see Chapter 3 above.

This study contains four sections. Section 1, Materials and Methods, starts by defining four realistic social welfare functions (i.e., potential desired fisheries worlds) based on a selection of the seven potential management objectives included in the microworld. It concludes with a discussion of the way in which scenarios will be run in the microworld. This aims to illustrate if and how policy instruments can be used to meet the four selected social welfare functions. Section 2 contains the actual results of these different scenarios, showing clearly how policy instruments can be used to meet the four selected social welfare functions. Section 3 discusses these results in the light of the effectiveness of fisheries management and provides practical suggestions in the form of general guidelines for improving fisheries management. Section 4 presents the conclusions drawn.

4.2 Materials and methods

4.2.1 The social welfare functions

Mathematically speaking, this microworld can create 5040 possible social welfare functions (factorial seven possible management objectives = 5040). Most of these are of course unrealistic or uninteresting. Therefore it is best to only investigate welfare functions that are realistic and interesting combinations of the four earlier discussed classes of management objectives, being (1) MSY, (2) MEY, (3) MJY, and (4) MSW. As such, decision has been made after consulting fisheries scientists of the Institute for Agricultural and Fisheries Research (ILVO) to focus this study on four social welfare functions (see Table 4.1) which represent the most extreme views on fisheries currently present in fisheries management discussions. The first social welfare function (SWF1) combines MJY with MEY, but MJY is predominant. SWF1 is therefore named "a bigger industry is a better industry" and primarily focuses on enhancing industry employment and therefore also fleet size. The second priority is the total industry value of the fishing industry. Consequently, policy instruments should be put in place that shape a regulatory environment for a large fishing industry that needs lots of employees while preserving its overall industry value. The second social welfare function (SWF2) is somewhat the opposite of SWF1 since it aims at MEY and not at MJY. In fact, even a small fleet (or at least a reduction in fishing effort) is preferred, since it is assumed to be an effective way of ensuring a profitable industry or MEY. The aim of SWF2 is thus to assure the firms and the people active in this small fishing industry high profits (or more generally speaking: high industry value per vessel) and good wages, respectively. Therefore, SWF2 is referred to as "small but wealthy". However, downsizing a fleet will not happen without social turbulence and tough management decisions. The third social welfare function (SWF3) solely aims to conserve (or install) social peace, being MSW, at minimal or low government expense. To make this happen, policy instruments should keep both the industry value per vessel and the average wages in the industry at least constant for the vast majority of the firms (preferably even slightly increasing over the years). Hence, SWF3 is labelled "keep them quiet and satisfied at low expenses". Finally, the last social welfare function (SWF4) is called "let's go green". This social welfare function's main objective is to have a sea full of fish to harvest in combination with a small ecological fleet. Although ecological dysfunctions of fishing are not included in the microworld, they will be alluded to when meeting this social welfare function in order to broaden the learning objectives of this study.

Table 4.1: Four selected social welfare functions with their relation to the seven management objectives included in the microworld ("+" = "Maximisation"; "-" = "Minimisation"; "=" = "Keep at least constant compared to the previous year"; and "Blank" = "not relevant")

Nr.	Label of the social welfare function	Total industry value	Industry value per vessel	Fleet size	Industry employment	Average wages	Government expenses	Estimated fish stock
SWF1	A bigger industry is a better industry!	+		+	+			
SWF2	Small but wealthy!		+	-		+		
SWF3	Keep them quiet and satisfied at low expenses!		=		=	=	-	
SWF4	Let's go green!			-				+

(Source: Own compilation)

4.2.2 The scenarios

Each scenario contains a policy strategy and has a time horizon of 20 years equal to the time horizon of the microworld (from year zero to year 20), with a time unit of one year and a time step (dt) of ¼ year. For each of the four selected social welfare functions, multiple scenarios will be run to illustrate how policy instruments can be used to meet their predefined management objectives. However, the objective of these scenarios is not to use the microworld to determine the optimal configuration of policy instruments that maximise each of these social welfare functions. This would be meaningless given the theoretical and learning nature of the microworld. In fact, this approach would even have conflicted with Johnson's (1995: 745) conclusion about the fact that models are more useful when used as tools to learn more about fisheries and options for management instead of predicting and optimising the future. As such, this study opts to derive scenarios (i.e., policy strategies) from socio-economic theory of fisheries, knowledge about fisheries management and fishery system behaviour (Sutinen, 1998). Extensive argumentation and discussion will guide the reader through each of these scenarios.

4.3 Results

4.3.1 Social welfare function 1: A bigger industry is a better industry!

Policymakers trying to meet this social welfare function should focus their efforts on shaping a regulatory environment for a large fishing industry that needs lots of employees while still remaining profitable. Since employment in fisheries is directly linked with fleet size, policymakers should put policy instruments in place that aim to increase fleet size. Because property rights, in this case fishing licences, mainly protect the industry from overcapacity by limiting the number of vessels (Arland *et al.*, 2002), fishing licences will play a vital role in allowing such a large fleet. However, setting those licences to a desired high level only shapes the condition for a large fleet. It does not naturally result in a large fleet, as it also needs to be financially attractive for potential investors to buy new vessels. This attractiveness is mainly determined by the return on investment (ROI) of the fleet or sub fleet the investor is trying to enter. In an attempt to enhance the attractiveness of investing in the fleet, policymakers can decide to use financial incentives such as investment subsidies. Such investment subsidies significantly increase the return on the investment, as they decrease the amount of private money that needs to be invested when buying new vessels. However, policymakers should be careful with both investment subsidies and licences because they each have a big downside - investment subsidies are government expenses and therefore paid by the general public (Cox, 2003). One should be well aware of this, together with the opportunity costs, since this influences (or at least should influence) the opinion of the general public about good governance. The downside with issuing many licences is the abovementioned problem of overcapacity. Overcapacity leads to fleets that cannot work at full capacity (e.g., a low capacity utilisation rate). This results in below-optimal revenues and therefore below-optimal net profit (Walden *et al.*, 2003). Overcapacity can have an enormous impact on industry performance and therefore on industry attractiveness and employment. As a result of these downsides, one should not be too generous with investment subsidies and licences.

Recalling the fact that a fleet cannot grow if it is not financially attractive to invest in new vessels, policy instruments should be put in place that shape a profitable environment for fishermen. Perhaps most important in shaping such a profitable environment is to ensure that the fish stock will not collapse, as they are of course the source of all revenues in fisheries. Total quota, when set at the scientifically recommended quota, allows, theoretically speaking, for maximal biological production and biological sustainability to happen (i.e., MSY). It is used as an output control to the fishing process (Greiner *et al.*, 2000; Sutinen, 1998) and is theoretically speaking a very good policy instrument to obtain biological sustainability (Greiner *et al.*, 2000), because it only allows fishermen to catch fish that are above the biomass that generates maximum production (i.e., B_{MSY}). However, in practice, the scientifically recommended quotas are at best delayed, and are rough estimates. As such, biological sustainability and especially maximal biological production due to quota management needs to be taken in reality with a (large) pinch of salt (e.g., Karagiannakos, 1996; Sutinen, 1998). Nevertheless, since the "Belgian Fisheries Microworld" is a theoretical microworld that includes a rather well-functioning scientific quota recommendation system, and given the social welfare function's aim at creating a large industry, it is desirable to follow these scientifically recommended quotas because it will ensure that the fish stock will not collapse due to overfishing. Further, as in Belgium, this total quota needs to be allocated over the different sub fleets, five of which are included in the microworld. This thus results in five group quotas. This allocation is no simple exercise, as the "best" allocation key needs to be determined, and "best" depends on the social welfare function.

There are also disadvantages to using total quota or total group quota restrictions. The most important disadvantage is that they enhance competitiveness among fishermen, resulting in a "race to fish" (Greiner *et al.*, 2000; Sutinen, 1998). This means that fishermen compete for a share of the quota before the total harvest limit is reached. This behaviour frequently results in certain fishermen investing in fishing capacity (e.g., more vessels, automation, increased engine power, more efficient fishing method) at the expense of others (Arland *et al.*, 2002; Greiner *et al.*, 2000; Sutinen, 1998). In turn, these investments and the race to fish increase overall harvesting costs, lower the total net returns from fishing and jeopardise the economic sustainability of fisheries (Grafton *et al.*, 2006; Greiner *et al.*, 2000; Sutinen, 1998). Consequently, in an attempt to eliminate this race-to-fish incentive, policymakers may prefer to ensure biological sustainability through controlling the input instead of the output of the fishing process (Greiner *et al.*, 2000; Sutinen, 1998). This is mainly done through decommissioning schemes and by implementing maximum fishing days (i.e., effort control), thereby limiting the amount of days fishermen are allowed to fish. Effort control strives for biological sustainability by indirectly managing the catches based on the assumption that fishery input and catch are positively correlated (Greiner *et al.*, 2000). However, although it eliminates the race-to-fish incentive (at least in abundant fisheries), it is no cure for overcapacity because it can still be financially interesting to invest in new vessels. Moreover, overcapacity can also still happen at the level of the individual vessel in the form of upgrading or modernisations in an attempt to maximise net profits per fishing day (i.e., technological creep). It is not clear which of these two policy instruments is best, since total quota and maximum fishing days have both positive and negative effects on the fishing system (for a more extensive overview of these effects see Danielsson, 2002; Georgianna *et al.*, 2008; Karagiannakos, 1996; Rossiter *et al.*, 2003; Sutinen, 1998). Consequently, they are often implemented simultaneously (e.g., the Common Fisheries Policy of the EU), presumably in a belief that they will counterbalance each other's negative effects or at least significantly reduce the risk of depleting the fish stocks.

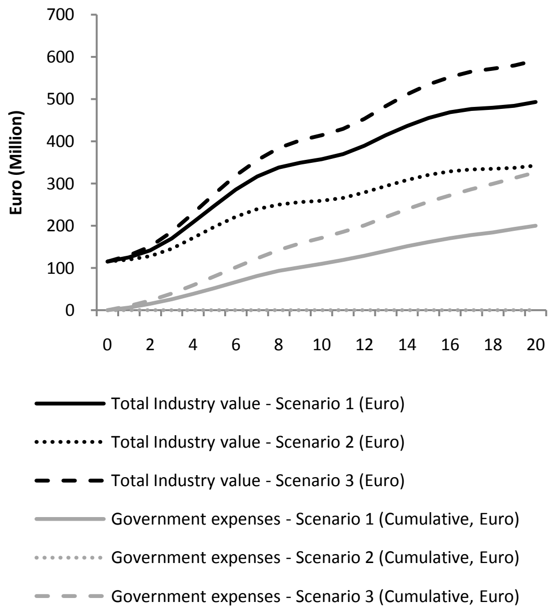
Based on this discussion the microworld is set up with the following policy strategy: (1) ten new licences per year, shaping the condition for a large fleet; (2) investment subsidies up to 50% of the price of a new vessel, giving high financial incentives to invest in new vessels; (3) total quota that are set equal to the scientifically recommended quota, for maximal biological production and biological sustainability; (4) equal allocation of the total quota among the five sub fleets; and (5) unlimited fishing days, as the total quota policy already exists for biological sustainability. Catch restrictions per fishing day, a policy instrument not commonly used outside of Belgium, are not implemented since these only limit the catch of the most productive vessels to the advantage of the others. As a result, this policy instrument does not contribute to meeting the social welfare function. Decommissioning fees and fuel subsidies are also not implemented, since government money will in this case primarily be used for investment subsidies. Additionally, fuel subsidies are, economically speaking, not the best way of spending government money since they do not structurally change the fisheries system (Mesnil, 2008). Nevertheless, fishermen frequently ask for them in times of very high fuel prices.

Table 4.2 and the solid lines in Figure 4.1-Figure 4.4 show the outcome of the microworld for this policy strategy. The figures illustrate that the policy strategy was successful in achieving the main objective of augmenting industry employment, since it increased almost linearly from initially 400 to 980 persons over the 20 years of simulation time. As such, total employment has more than doubled. The same holds true for the fleet size, which has also more than doubled, from 125 to 335 vessels, due to the financial attractiveness (i.e., high ROIs) of the industry during these 20 years. Hence, this increase in fleet size made the increase in employment possible. When looking at the total industry value, it initially started off at 115M euro and increased after 20 years to 493M euro. The reason for this is the increase in new industry assets (through the increase of new vessels) in combination with profitable vessels that are able to build up savings. As a result, these findings certainly illustrate that the created regulatory environment has resulted into a "bigger" fishing industry with regard to (1) industry employment, (2) fleet size and (3) financial scale. However, this policy strategy comes at a price. Firstly, the total cumulative government expenses after 20 years were 200M euro, meaning that 10M euro of public money was spent annually on investment subsidies alone. Secondly, although this policy strategy initially resulted in an increase in the average industry value per vessel from initially 0.92M to almost 1.60M euro by year 15, it fell back to 1.47M euro by the end of year 20. This negative trend after year 15 is mainly caused by the race-to-fish behaviour, since a similar amount of fish (i.e., the total quota) is now exploited by a larger fleet. This results in reduced catch per unit efforts (CPUE). This in turn reduces the profitability of the fleet and eventually results in decreasing average industry value per vessel. Finally, the average wages in the industry have perhaps suffered most under this policy strategy. Since these wages are in Belgian fisheries a fixed proportion (i.e., normally 1/3) of the revenues a vessel makes, low catches per vessel due to low CPUE results in low revenues which therefore also results in low average wages (i.e., 32780 euro after 20 years of simulation time: a 28% reduction). Lastly, it is also interesting to notice that the behaviour of the estimated fish stock is a slightly damping oscillation, which illustrates that following the recommended quota has prevented the fish stock from depletion. This damping oscillating behaviour is caused by the delays in (1) the estimation of stock dynamics and (2) the process of smoothly adjusting the recommending quota. In sum, it may be stated that this policy strategy does result in creating a vast industry and therefore meets the social welfare function. This came at a certain cost of scoring badly on other less important objectives since both average industry wages and industry value per vessel were low and government expenses were rather high.

As a result, one wonders if the high government expenses in the form of investment subsidies were really necessary. After all, administering investment subsidies transfers money from the general public to the fishing community (Cox, 2003). Therefore, it would be interesting to see if a vast industry could still be created without investment subsidies. A second scenario omits investment subsidies from the original policy strategy (under the "ceteris paribus" clause). The outcome for this scenario is represented by the dotted lines (small dots) in Figure 4.1-Figure 4.4 (see also Table 4.2). It is clear from these figures that even without investment subsidies, both industry employment and fleet size had still more than doubled in 20 years' time. There are now 939 persons working in fisheries on 323 vessels after 20 years of simulation time instead of 980 persons on 335 vessels. Hence, they were both eventually only four percent lower than the original policy strategy. This outcome is not expected, as it is assumed that investment subsidies significantly accelerate fleet expansion. However, in this case, it remains highly financially attractive for potential investors to buy new vessels due to the high ROIs in the industry. Additionally, omitting investment subsidies from the policy strategy did not result in major changes in average wages and estimated fish stock. However, the main difference lies within the significantly lower total industry value and average industry value per vessel, mainly because government is not financially supporting the increase in fleet size anymore through investment subsidies. Total industry value and average industry value per vessel were, after 20 years, both roughly 30 percent lower compared to the original policy strategy; they were 150M euro and 0.4M euro lower, respectively. It is interesting that 200M euro of investment subsidies eventually only result in 150M euro of additional industry value in the original policy strategy. This results in a quarter of the invested government money leaving the fishing industry. The reason for this is that the original policy strategy invests government money in overcapacity (i.e., due to the race-to-fish behaviour of the fishermen who are eager to invest in overcapacity since they want to ensure a larger share of the quota). In sum, even without investment subsidies, the industry remains large with regard to industry employment and fleet size (only 4% difference with the original policy strategy), but it is not large in its financial scope anymore. As such, investment subsidies are effective in enhancing total industry value, but one should beware of government money draining away in overcapacity.

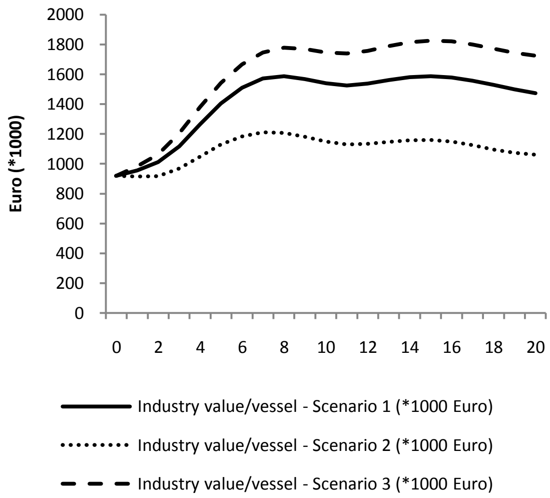
Last, it may also be interesting to see what the effect would be if fuel subsidies were administered on top of the original policy strategy since it is assumed by fishermen that such subsidies vastly contribute to the fleet's economic performance. To test this policy strategy, fuel subsidies are set to 20% of the fuel price (under the “ceteris paribus” clause). The outcome of this scenario is given by the dashed lines (long dashes) in Figure 4.1-Figure 4.4 (see also Table 4.2). This addition to the original policy strategy only marginally contributes to both total industry employment and total fleet size; respectively only 53, or 5%, more persons and 8, or 2%, more vessels by the end of year 20. Nor does it have any significant effect on average wages (only 5% higher in year 20), nor on the estimated fish stock. The main difference lies in the increase in total industry value and average industry value per vessel; these were 98M euro or 20%, and 0.25M euro or 17% lower, respectively. This difference is made purely by the vast amount of government money poured into the industry in the form of fuel subsidies. However, 126M euro of fuel subsidies only resulted in 98M euro additional industry value. This ratio is not expected, as again the government money drains out of the fishing industry. Since the amount of government expense is inferior to creating a large industry, including fuel subsidies in the original policy strategy contributes to SWF1. However, when taking into account the pros and cons of adding fuel subsidies to the original policy strategy, it is neither economically rational nor necessary to implement fuel subsidies on top of the original policy strategy.

Figure 4.1: Outcomes for "total industry value" (€) and "government expenses" (€) for the different policy strategies (scenarios) to meet social welfare function 1 ("A bigger industry is a better industry")



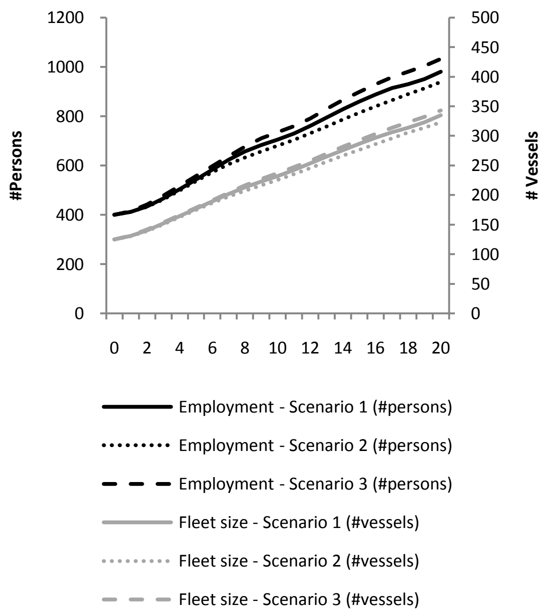
(Source: Own compilation)

Figure 4.2: Outcome for "total industry value per vessel" (€) for the different policy strategies (scenarios) to meet social welfare function 1 ("A bigger industry is a better industry")



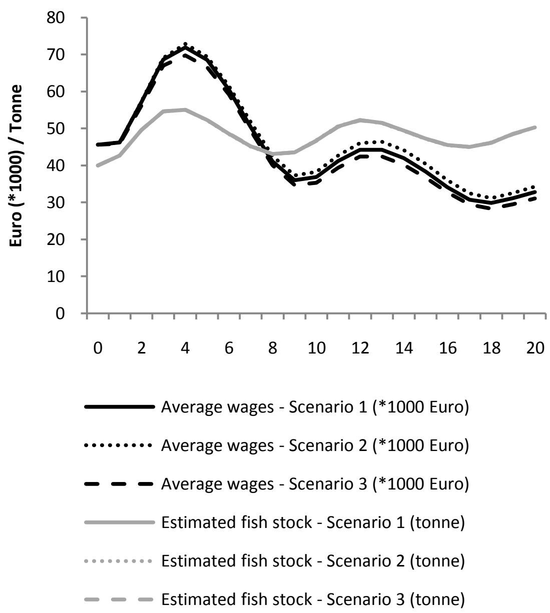
(Source: Own compilation)

Figure 4.3: Outcomes for "employment" (#persons) and "fleet size" (#vessels) for the different policy strategies (scenarios) to meet social welfare function 1 ("A bigger industry is a better industry")



(Source: Own compilation)

Figure 4.4: Outcomes for "average wages" (€) and "estimated fish stock" (tonne) for the different policy strategies (scenarios) to meet social welfare function 1 ("A bigger industry is a better industry")



(Source: Own compilation)

Table 4.2: Overview of the results for the different scenarios aiming to meet social welfare function 1 ("A bigger industry is a better industry!") ("SWF" = "Social Welfare Function")

SWF1: A BIGGER INDUSTRY IS A BETTER INDUSTRY!

Management objectives[a]:

Total industry value	+
Fleet size	+
Industry employment	+

Scenario	Policy strategy	Outcome on management objectives[b]		Evaluation[c]
1	Quota = recommended quota	Total industry value	493M euro	+++
	Quota equally allocated over sub fleets	Industry value per vessel	1.47M euro	
	Unlimited fishing days	Fleet size	335 vessels	
	Ten new licences per year	Industry employment	980 persons	
	Investment subsidies = 50% of price new vessel	Average wages	32777 euro	
		Government expenses	200M euro	
		Estimated fish stock	50.27 tonne	
2	Quota = recommended quota	Total industry value	343M euro	+
	Quota equally allocated over sub fleets	Industry value per vessel	1.06M euro	
	Unlimited fishing days	Fleet size	323 vessels	
	Ten new licences per year	Industry employment	939 persons	
		Average wages	34237 euro	
		Government expenses	0 euro	
		Estimated fish stock	50.29 tonne	
3	Quota = recommended quota	Total industry value	591M euro	+
	Quota equally allocated over sub fleets	Industry value per vessel	1.72M euro	
	Unlimited fishing days	Fleet size	343 vessels	
	Ten new licences per year	Industry employment	1032 persons	
	Investment subsidies = 50% of price new vessel	Average wages	31060 euro	
	Fuel subsidies = 20% of the fuel price	Government expenses	326M euro	
		Estimated fish stock	50.23 tonne	

a: where "+" means "as high as possible"; "-" means "as low as possible"; and "=" means "keep at least constant compared to the previous year".
b: by the end of the 20 years of simulation time
c: range from "+++" meaning "very good policy strategy" to "---" meaning "very bad policy strategy".

4.3.2 Social welfare function 2: Small but wealthy!

This social welfare function is sought through shaping a regulatory environment that primarily focuses on high average industry value per vessel. Since average industry value per vessel is a ratio with total industry value as the numerator and number of vessels in the fleet as the denominator, its value increases when (1) total industry value increases or (2) total fleet size decreases (or when both happen simultaneously). Previous scenarios related to SWF1 have illustrated that total industry value can mainly be increased by expanding the fleet through investment subsidies and shaping a regulatory environment that allows high profits.

However, for this social welfare function, expanding the fleet would not be such a good idea since this would also increase the denominator in the "average industry value per vessel"-ratio. To meet this SWF, the fleet should be converted and if necessary reduced to one that is highly profitable without losing too many industry assets (i.e., industry value). In general, industry assets are mainly lost (1) when vessels encounter financial losses and (2) when vessels are scrapped or sold for less than their remaining value (given the microworld's assumption that the money remains in the fishing industry). As a result, the fleet should be reconverted based on decommissioning fees that equal the remaining value of the vessels. This would give non-profitable vessels important incentives to leave the fleet but would not deplete industry assets. Consequently, in a first policy strategy, decommissioning fees are set at the average remaining value of the vessels. Additionally, recalling the fact that it would be unwise to allow the current fleet to expand, zero new licences are allowed per year. This zero value is also the only way in which decommissioning fees are able to reduce long-term fishing effort (in the form of reduced fleet size) and help stocks recover (Grafton *et al.*, 2006; Holland *et al.*, 1999).

A regulatory environment that allows high profits requires a sustainable fish stocks greater than that which may maximize biological production. The scenarios related to SWF1 illustrate that following the scientifically recommended quota is a robust strategy to ensure sustainable fish stocks. However, compared to SWF1, the likelihood of depleting the fish stock is now considerably lower since the focus is now on a small fleet. Next, the allocation of quota among the sub fleets and the amounts of maximum fishing days for each sub fleet are both policy instruments that can be used to convert the fleet towards a more profitable one by pushing out the less profitable vessels. Chapter 2 of this dissertation has studied the profitability of the five Belgian sub fleets included in this microworld and found that large beam trawlers need to catch much more fish compared to the other sub fleets in order to be as financially viable. This is not beneficial for SWF2. Therefore, the first scenario below opts to push large beam trawlers out of the fleet, leaving more fish for the others. For this to happen, this scenario allocates the total quota as follows: (1) 6/25 for small beam trawlers, (2) 2/25 for large beam trawlers, (3) 7/25 for otter trawlers, (4) 5/25 for trammel netters and (5) 5/25 for shrimp beam trawlers. Next, there are no restrictions to the amount of fishing days, nor are there catch restrictions per fishing day. Finally, investment subsidies and fuel subsidies are not used, as government money in this case should primarily be going to decommissioning fees.

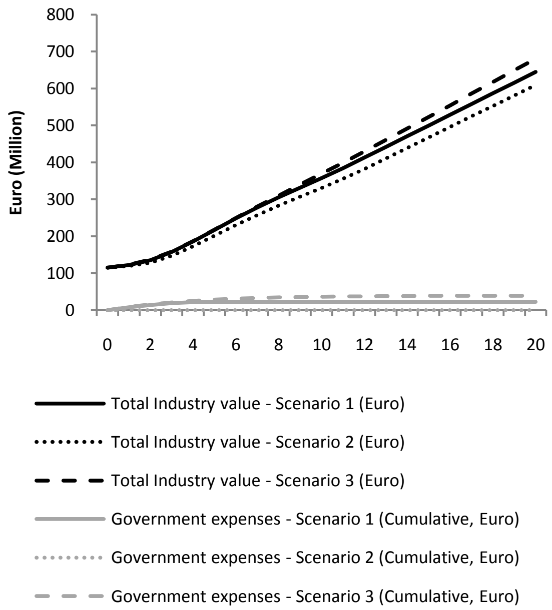
The solid lines in Figure 4.5-Figure 4.8 are the outcome of this scenario (i.e., policy strategy) (see also Table 4.3). The main target of increasing average industry value per vessel has definitely been successful, since it has multiplied nearly six times over 20 years, following an almost linear increase from 0.9 to 5.7M euro per vessel. This is caused by the fact that total industry value (i.e., its numerator) has also multiplied almost six times from 115M to 644M euro, whereas the fleet size (i.e., its denominator) was reduced by 10% from 125 to 113 vessels. This policy strategy also caused average wages to double, from 45000 to 89000 euro. Consequently, this combination tremendously increased average industry value per vessels and almost doubled average wages. This clearly illustrates that SWF2 can be met through applying this current policy strategy. However, the graphs also illustrated that this policy strategy comes at a cost of a 10% reduction in fleet size. As a result of this reduction in fleet size, total industry employment also reduced from 400 to 339 persons by the end of year 20; a reduction of 18%. Finally, it is also interesting to notice that government expenses are very small (only 22M after 20 years) and that the estimated fish stock behaves like a damping oscillation towards the level that seems to generate maximum production. In sum, this policy strategy resulted indeed in a wealthy fleet, both in terms of industry value per vessel and average wages. However, this reduced the fleet size and therefore also reduced industry employment.

Having investigated this policy strategy, the following question arises: how does paying decommissioning fees equal to the remaining value of the vessels impact the fisheries system? To answer this question, a new scenario was run with exact the same policy strategy except with decommission fees set to zero (under the "ceteris paribus" clause). The outcome of this scenario is given by the dotted lines (small dots) in Figure 4.5-Figure 4.8 (see also Table 4.3). It is clear from these graphs that the lack of decommission fees lowers the average industry value per vessel with 0.84M euro or 15% in year 20 compared to the original policy strategy. This reduction is caused by a 5% or 35M euro reduction in total industry value in combination with a fleet that keeps 125 vessels over the 20 years of simulation time. Paying decommissioning fees certainly contributes to meeting the main objective of SWF2 by buying out vessels much faster than the market would. It is also interesting to note that 22M euro of decommissioning fees results in 35M euro additional industry value. Consequently, government money and therefore public money (Cox, 2003; Grafton *et al.*, 2006) is in this case better spent compared to the investment subsidies in the original policy strategy of SWF1. This makes this finding counterintuitive. As noted previously, eliminating decommissioning fees from the policy strategy also results in a constant total fleet size of 125 vessels. However, the relative sizes of the sub fleets mutually do have changed (data not shown). Large beam trawlers left the fleet and their licences became available for others since they were not decommissioned. These licences were then used by the other profitable sub fleets to expand their fleet size. Consequently, industry employment was also higher compared to the original policy strategy (i.e., 35 persons or 10%). Finally, the outcome for the estimated fish stock did not differ compared to original policy strategy and therefore neither did the quota. As such, more vessels were now "hunting" for the same amount of fish (i.e., total quota), resulting in lower average revenues per vessel and therefore lower average wages (i.e., 7000 euro or 8% lower). In sum, administering decommissioning fees certainly contributes to meeting SWF2 and to the fisheries system as a whole. Therefore, they should not be omitted from the original policy strategy.

The final scenario allocates no quota at all to the large beam trawlers. This pushes them out of the fleet immediately (under the "ceteris paribus" clause). Although this policy strategy is perhaps highly unrealistic to implement, it still is interesting to see how this would affect the fisheries system. The outcome of this policy strategy is given by the long dashed lines in Figure 4.5-Figure 4.8 (see also Table 4.3). These graphs illustrate that the average industry value is 1.06M euro (or 19%) higher by year 20 compared to the original policy strategy.

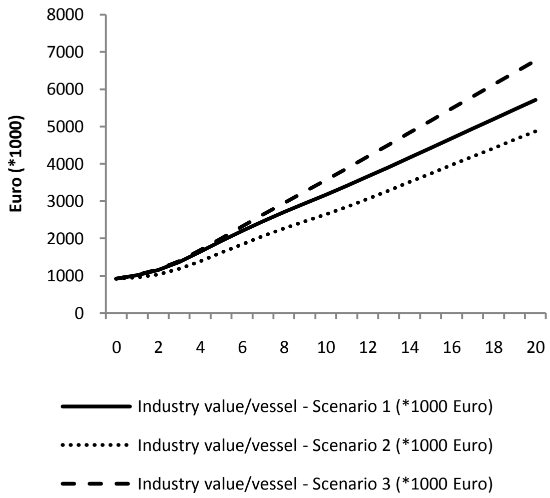
Additionally, average wages also increased 20% or 18000 euro. In contrast to the original policy strategy, average wages remain at the same level after five years. The strategy of pushing out the large beam trawler fleet immediately by giving them no group quota thus definitely improves the original policy strategy to meet SWF2. However, this improvement comes at a higher governmental cost, since government expenses are now 17M or 76% higher, because more large beam trawlers were decommissioned. Nevertheless, this additional 17M euro of decommissioning fees resulted in an additional 36M euro (6%) in total industry value. This additional value thus generously compensates for the additional government expenses. This policy strategy also results in a fleet and employment level that are 12 vessels (10%) and 61 persons (18%) lower, respectively, than the original policy strategy. However, when one is striving for SWF2, one is willing to accept this cost because of the vast increase in both average industry value per vessel and average wages.

Figure 4.5: Outcomes for "total industry value" (€) and "government expenses" (€) for the different policy strategies (scenarios) to meet social welfare function 2 ("Small but wealthy")



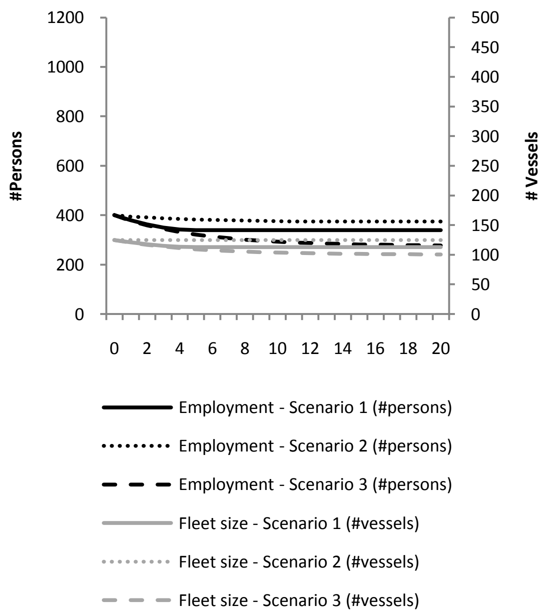
(Source: Own compilation)

Figure 4.6: Outcome for "total industry value per vessel" (€) for the different policy strategies (scenarios) to meet social welfare function 2 ("Small but wealthy")



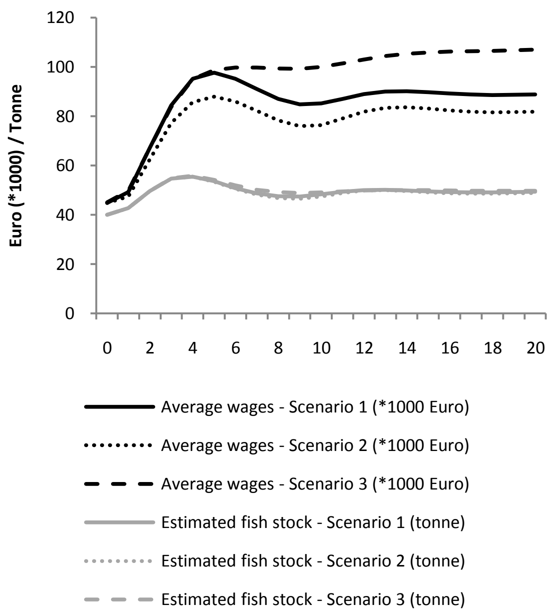
(Source: Own compilation)

Figure 4.7: The outcomes for "employment" and "fleet size" for the different policy strategies (scenarios) to meet social welfare function 2 ("Small but wealthy").



(Source: Own compilation)

Figure 4.8: The outcomes for "average wages" and "estimated fish stock" for the different policy strategies (scenarios) to meet social welfare function 2 ("Small but wealthy").



(Source: Own compilation)

Table 4.3: Overview of the results for the different scenarios striving for social welfare function 2 (“Small but wealthy!”) (“SWF” = “Social Welfare Function” and “LBT” = “Large Beam Trawler”)

SWF2: SMALL BUT WEATHY!

Management objectives[a]:

Industry value per vessel	+
Fleet size	-
Average wages	+

Scenario	Policy strategy	Outcome on management objectives[b]		Evaluation[c]
1	Quota = recommended quota Quota unequally allocated over sub fleets in which 2/25 to LBT Unlimited fishing days Decommissioning fees = remaining value of vessel	Total industry value Industry value per vessel Fleet size Industry employment Average wages Government expenses Estimated fish stock	644M euro 5.71M euro 113 vessels 339 persons 88796 euro 22.37M euro 49.31 tonne	++
2	Quota = recommended quota Quota unequally allocated over sub fleets in which 2/25 to LBT Unlimited fishing days	Total industry value Industry value per vessel Fleet size Industry employment Average wages Government expenses Estimated fish stock	609M euro 4.87M euro 125 vessels 374 persons 81825 euro 0M euro 48.83 tonne	-
3	Quota = recommended quota Quota unequally allocated over sub fleets in which nothing to LBT Unlimited fishing days Decommissioning fees = remaining value of vessel	Total industry value Industry value per vessel Fleet size Industry employment Average wages Government expenses Estimated fish stock	681M euro 6.77M euro 101 vessels 278 persons 106943 euro 39.33M euro 49.78 tonne	+++

a: where “+” means “as high as possible”; “-” means “as low as possible”; and “=” means “keep at least constant compared to the previous year”.
b: by the end of the 20 years of simulation time
c: range from “+++” meaning “very good policy strategy” to “---” meaning “very bad policy strategy”.

4.3.3 Social welfare function 3: Keep them quiet and satisfied at low expenses!

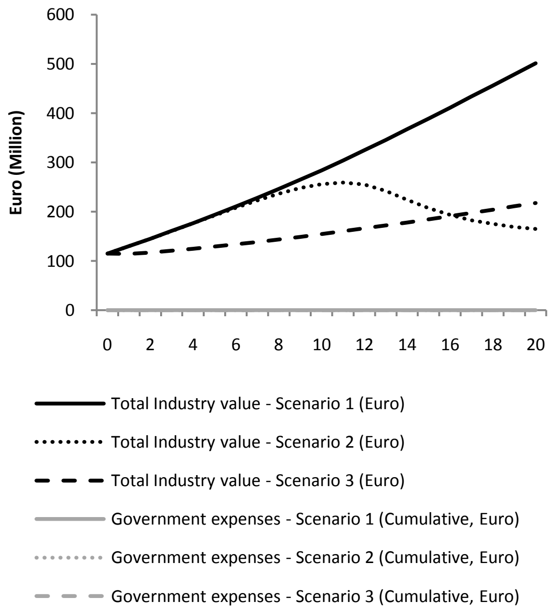
The main objective of this social welfare function is to have a stable fishing industry in which shipping companies and crews are both earning good money. Setting total quota equal to the scientifically recommended quota would have been a starting point for building such stability into the fisheries system. However, previous scenarios have illustrated that total quota are only able to build relative stability into the fisheries system. This means that there are still fluctuations in the fisheries system caused by fluctuations in the total quotas because they are delayed (i.e., the observed damping oscillating behaviour of estimated fish stocks). As such, biological sustainability is sought in this scenario through limiting both (1) the days fishermen can go fishing and (2) licences. The reason why maximum fishing days are preferred to total quota is that they can be more easily kept constant over the years without becoming a subject of major social pressure. In fact, effort restrictions, and especially maximum fishing days, are regularly reported by fishermen as their preferred policy instrument (Rossiter *et al.*, 2003). One important reason for this is that they believe it brings stability to their business and transparency towards the future (Rossiter *et al.*, 2003). Hence, this policy strategy opts to give each vessel 200 fishing days. Giving each vessel the same amount of fishing days ensures equality among sub fleets and thus contributes to social peace. However, only limiting a vessel's maximum fishing days does not necessarily result in biological sustainability because overcapacity also needs to be restrained. Since overcapacity in this microworld can only be manifested in an over-expanded fleet size, setting yearly new licences to zero will stop additional overcapacity from happening. Next, total quota policy should be switched off in the microworld. However, this is not technically possible. Therefore, the next best option is to set the quota unrealistically high, which virtually equals no quota at all. Consequently, this eliminates the way in which the total quota is allocated over the five sub fleets. Finally, since this social welfare function aims at social peace with a limited amount of government expenses, all forms of subsidies and fees should be limited. This scenario interprets "limited" very strictly and therefore provides no investment subsidies, decommissioning fees or fuel subsidies at all. Last, catch restrictions per fishing day are also set to zero.

The full lines in Figure 4.9-Figure 4.12 give the outcomes for this scenario (see also Table 4.4). The five horizontal or almost horizontal lines are striking in these graphs: (1) industry employment, which remained constant over the years at 400 persons, (2) fleet size, which also stayed constant at 125 vessels, (3) government expenses, which remained zero, (4) average wages, which increased by only 8% (from 67000 to 72500 euro), and (5) the estimated fish stock, which steadily increased its biomass from 40 to 51 tonnes by the end of year 20 (i.e., 28%). The total industry value and industry value per vessel increased more than fourfold, from 115M to 501M euro and from 0.92M to 4.01M euro, respectively. As such, these findings illustrate a fishing environment that is likely to have a high degree of social peace, given that (1) the industry is highly profitable and profitability is still increasing, (2) average wages are high and are also still increasing, and (3) the remainder of the fisheries system is stable.

Although this policy strategy seems successful in meeting SWF3, it is also interesting to check what happens if the policy strategy allows room for fleet expansion. To test this, the original policy strategy is now extended with one new additional licence per year (under the "ceteris paribus" clause). The dotted lines (small dots) in Figure 4.9-Figure 4.12 illustrate how devastating this new policy strategy is for the entire industry (see also Table 4.4). Both total industry value and average industry value per vessel are more than 60% lower in year 20 compared to the original policy strategy (i.e., 336M and 2.45M euro, respectively). Moreover, both their trajectories fall after first having increased. This behaviour can be mainly explained by the collapse in the fish stock (and therefore also revenues) in the second half of the simulation time in combination with vessels (i.e., industry assets) leaving the fleet as a reaction to this collapse. To be more precise, by the end of year 20, the estimated fish stock is dramatically depleted by 53% (21280 tonne), and the fleet size ends with 19 vessels (or 16%) less than the original policy strategy. This also reduces employment by 75 persons (or 19%). This policy strategy also severely negatively impacted average wages, which decreased by more the 50% (or 34054 euro) by the end of year 20. This is a counterintuitive result, given that the fleet was allowed to expand. One presumes that these behaviours will not preserve social peace in the long run. It is thus no understatement to say that this scenario has proven the importance of strict licence limitations in the original policy strategy in order to ensure social peace. Even allowing one additional licence per year had a devastating impact on social peace.

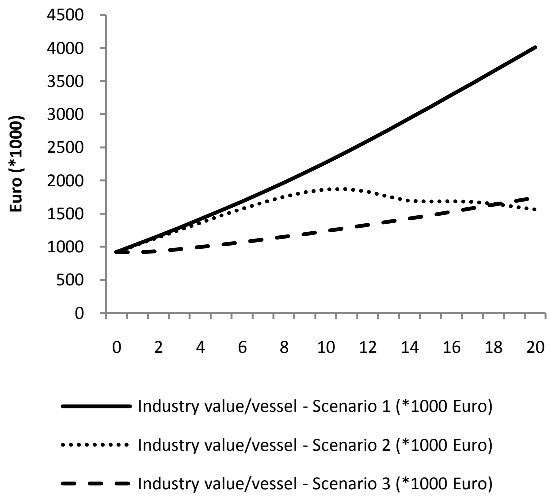
One last scenario illustrates all the missed opportunities for the fisheries system when the maximum fishing days are too severely limited (i.e., too low), for instance 100 fishing days instead of 200 (under the "ceteris paribus" clause). The outcome of this policy strategy is given by the long dashed lines in Figure 4.9-Figure 4.12 (see also Table 4.4). These graphs illustrate that when vessels have only 100 fishing days instead of 200, both total industry value and average industry value per vessel only increase by 103M and 0.82M euro, respectively, instead of 386M and 3.09M euro as in the original policy strategy. Nevertheless, in the absence of knowing the outcome of the original policy strategy, there is no reason to suspect that this would lead to social unrest, as both increase linearly over the 20 years of simulation time. However, comparison of this policy strategy with the original one reveals a large amount of unexploited industry value: revenues are capped because the fishing effort is so strictly regulated. Similarly, average wages remain constant after two years of slight increase. Compared to the original policy strategy, wages are 33750 euro or 47% lower by the end of year 20. In contrast, both fleet size and industry employment were virtually the same at a constant level of 125 vessels and 400 employees, respectively, and the estimated fish stock is better off compared to the original policy strategy (almost 70000 tonne). The latter is no surprise, given the strictly limited number of fishing days. In sum, following the policy strategy of strictly limited fishing days will probably not result in social disorder, but nor will it result in a high level of social peace, since it misses important opportunities for the fishing industry and system as a whole.

Figure 4.9: Outcomes for "total industry value" (€) and "government expenses" (€) for the different policy strategies (i.e., scenarios) to meet social welfare function 3 ("Keep them quiet and satisfied at low expenses")



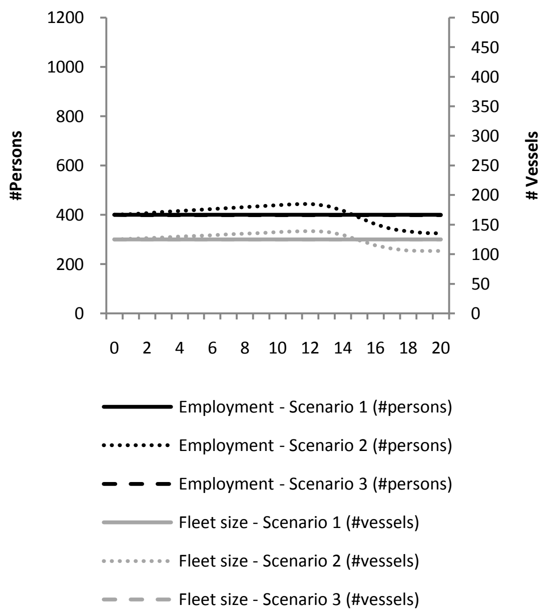
(Source: Own compilation)

Figure 4.10: Outcome for "total industry value per vessel" (€) for the different policy strategies (i.e., scenarios) to meet social welfare function 3 ("Keep them quiet and satisfied at low cost")



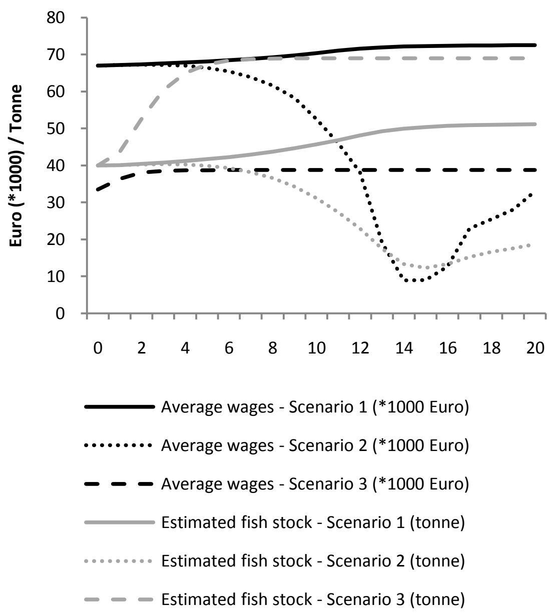
(Source: Own compilation)

Figure 4.11: Outcomes for "employment" (#persons) and "fleet size" (#vessels) for the different policy strategies (i.e., scenarios) to meet social welfare function 3 ("Keep them quiet and satisfied at low cost")



(Source: Own compilation)

Figure 4.12: Outcomes for "average wages" (€) and "estimated fish stock" (tonne) for the different policy strategies (i.e., scenarios) to meet social welfare function 3 ("Keep them quiet and satisfied at low cost")



(Source: Own compilation)

Table 4.4: Overview of the results for the different scenarios aiming at meeting social welfare function 3 ("Keep them quiet and satisfied at low expenses!") ("SWF" = "Social Welfare Function")

SWF3: KEEP THEM QUIET AND SATISFIED AT LOW EXPENSES!

Management objectives[a]:

Industry value per vessel	=
Industry employment	=
Average wages	=
Government expenses	-

Scenario	Policy strategy	Outcome on management objectives[b]		Evaluation[c]
1	No quota	Total industry value	501M euro	+++
	200 fishing days per vessel	Industry value per vessel	4.01M euro	
		Fleet size	125 vessels	
		Industry employment	400 persons	
		Average wages	72502 euro	
		Government expenses	0M euro	
		Estimated fish stock	51.13 tonne	
2	No quota	Total industry value	165M euro	---
	200 fishing days per vessel	Industry value per vessel	1.56M euro	
	One new licence per year	Fleet size	106 vessels	
		Industry employment	325 persons	
		Average wages	32947 euro	
		Government expenses	0M euro	
		Estimated fish stock	18.72 tonne	
3	No quota	Total industry value	218M euro	-
	100 fishing days per vessel	Industry value per vessel	1.74M euro	
		Fleet size	125 vessels	
		Industry employment	399 persons	
		Average wages	38751 euro	
		Government expenses	0 euro	
		Estimated fish stock	69.02 tonne	

a: where "+" means "as high as possible"; "-" means "as low as possible"; and "=" means "keep at least constant compared to the previous year".
b: by the end of the 20 years of simulation time
c: range from "+++" meaning "very good policy strategy" to "---" meaning "very bad policy strategy".

4.3.4 Social welfare function 4: Let's go green!

This social welfare function is ecological in nature, since it aims at high levels of biomass in the sea in combination with a small ecological fleet. To ensure high biomass, quota recommendations are not followed. Instead, actual total quota is set at only half the recommended quota. In practice, this means that MSY is abandoned and biologically maximum production is not sought. More concern now goes to the well-being of the aquatic resources. This may seem disastrous for the fishing industry at first glance, but there still is an advantage since such a policy strategy almost certainly results in higher fish densities and allows vessels to catch their fish more efficiently (i.e., high CPUE). This reduces the time and effort spent harvesting the total quota and consequently reduces operational costs. In sum, this quota policy will lead to reduced catch and revenues due to the lower total quota, but it will also lead to a more than proportional reduction in operational costs since quota are lower and CPUE will be higher. Hence, vessels can remain profitable if their share of fixed costs in the total costs is low. Next, total quota needs to be allocated over the different sub fleets, which for this policy strategy will be done in the light of converting the fleet into an ecological one. Since flatfish beam trawling is commonly known to be environmentally unfriendly (Anon., 2005; Hilborn, 2007b; Lindeboom *et al.*, 1998; Polet *et al.*, 2006; Polet *et al.*, 2007), this sub fleet should be reduced. This scenario thus allocates the total quota as follows: (1) 2/25 for small beam trawlers, (2) 2/25 for large beam trawlers, (3) 7/25 for otter trawlers, (4) 7/25 for trammel netters and (5) 7/25 for shrimp beam trawlers.

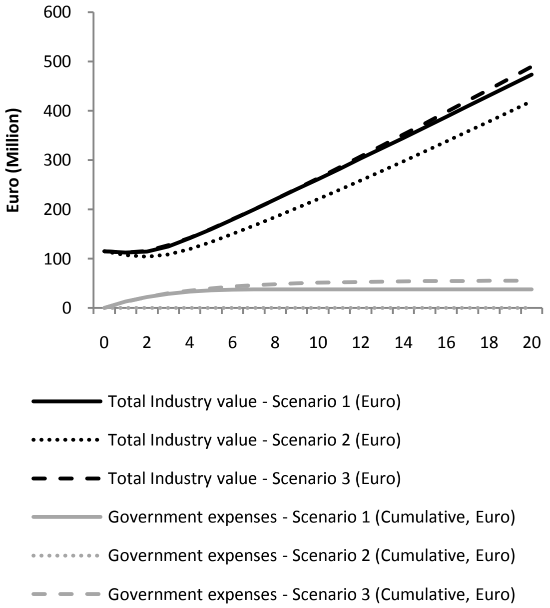
Since the total quota is set at half the recommended quota, this policy strategy chooses not to restrict the number of fishing days. New licences per year is set to zero, in line with the ecological character of the social welfare function. Decommissioning fees are set equal to the remaining value of the vessels, which gives non-profitable vessels an incentive to leave the fleet. The fees are set high because this also ensures that when vessels leave the fleet, their licences are destroyed. Next, given that government money in this case goes primarily to these decommissioning fees, investment subsidies and fuel subsidies are set to zero. Finally, catch per fishing day restrictions are not used because they are ecologically pernicious. Limits on the catch a vessel can land per fishing day almost certainly results in high grading, which in turn leads to a high mortality of many discarded species (Cappell, 2001; Catchpole *et al.*, 2005; Lindeboom *et al.*, 1998; Wileman *et al.*, 1999).

The outcome for this policy strategy is given by the full lines in Figure 4.13-Figure 4.16 (see also Table 4.5). The main target of having plenty of fish in the sea has been well reached, since the fish stock increases its biomass from 40000 tonnes to more than 65000 tonnes by the end of the simulation time. This is mainly caused by setting the quota at half the recommended quota, which very effectively preserves the fish stock. Additionally, the second objective of reducing and converting the fleet towards a small and ecological one has also been successful since (1) the total fleet size has decreased from 125 to 96 vessels (a reduction of 23%) by the end of the simulation time; and (2) both the large beam trawler fleet and the small beam trawler fleet were reduced by 64% (or 16 vessels) and 44% (or 11 vessels), respectively, whereas the trammel netter fleet, the shrimp beam trawler and the otter trawler fleet remained constant (the otter trawlers only encountered a small loss of two vessels). However, as a result of this decrease in fleet size, industry employment fell from 400 to 282 persons; a reduction of 29%. Although the ecological focus exacts a heavy cost for the fishing industry, there is also an economically positive side to these sacrifices. Total industry value has increased more than fourfold (from 115M to 473M euro) and average industry value per vessel has increased even more than fivefold (from 0.92M to 4.91M euro). The same is true for average wages; they have more than tripled from 23370 to 75400 euro. These financial outcomes were not expected since we halved the recommended quota. The conversion and reduction of the fleet resulted in highly profitable fisheries. Lastly, this policy strategy also results in low government expenses of only 38M euro after 20 years. In sum, this ecological policy strategy ensures a bright economic future, albeit only for the employees of the ecological sub fleets that are able to remain in the industry.

Decommissioning fees probably play an important role in this policy strategy since there is some similarity between this policy strategy and the one employed for meeting SWF2. To quickly test this, the microworld is rerun but now with the elimination of decommission fees from the original policy strategy (under the "ceteris paribus" clause) (see small dotted lines in Figure 4.13-Figure 4.16; see also Table 4.5). In this case, the fleet does not decrease to 96 but remains constant at its initial level of 125 vessels. As such, when licences became available, they were immediately used by the other profitable sub fleets to expand their fleet size. Hence, the composition of the fleet changed to 20 small beam trawlers, 10 large beam trawlers, 29 otter trawlers, 33 trammel netters and 33 shrimp beam trawlers. In sum, high decommissioning fees are necessary to be sure that licences become destroyed when vessels exit the fleet. As a result of not reducing the fleet size, industry employment was also 80 employees higher by year 20 compared to the original policy strategy. Next, omitting decommissioning fees from the original policy strategy also had an enormous impact on the total industry value and average industry value per vessel. In fact, total industry value is 11% (or 54M euro) lower whereas average industry value per vessel is even 32 percent lower (or 1.55M euro) compared to the original policy strategy. Hence, administering decommission fees equal to the remaining value of the decommissioned vessels cost 38M euro after 20 year but resulted into 54M additional industry value. Average wages were also 17 percent lower (or 13070 euro) (because revenues were lower since more vessels were competing for the same amount of quota) and the estimated fish stock was slightly worse off (i.e., a slight decrease of 0.69 tonne or 1%) compared to the original policy strategy. In sum, these are all similar findings as compared to the findings on the policy strategy for SWF2 when decommissioning fees were omitted, except for the slight decrease in estimated fish stock. However, although the fact that both social welfare functions aim at different object functions, administering decommissioning fees also contributes to meeting the ecological character of SWF4 through reducing the fleet.

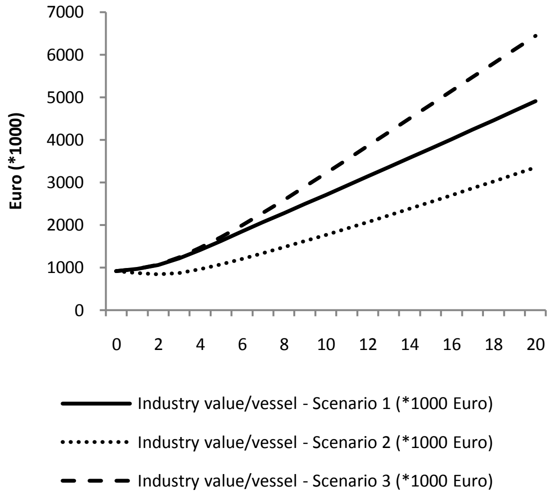
Finally, and to completely follow the same structure of policy tests as for SWF2, large beam trawlers and small beam trawlers were immediately pushed out of the fleet by setting their quota share to zero (under the "ceteris paribus" clause). The dotted lines (small dots) in Figure 4.13-Figure 4.16 give the results of this policy strategy (see also Table 4.5). Compared to the original policy strategy, the estimated fish stock has only increased by 9000 tonnes or 1%. However, the total fleet size was 21% (or 20 vessels) lower by the last year of the simulation run. Additionally, the large beam trawler fleet and small beam trawler fleet has completely disappeared. The otter trawlers, trammel netters and shrimp beam trawlers have not decommissioned vessels as they remained profitable over the years. Consequently, this rigid policy strategy resulted in a more ecological fleet but not in a significant increase of the fish stock compared to the original policy strategy. The latter is quite counterintuitive since one would have expected that pushing out the whole large beam trawler fleet and small beam trawler fleet would have resulted in a significant increase in estimated fish stock. However, the estimated fish stock was in the original policy strategy already very high. Therefore, net increase in fish stock becomes more difficult given the microworld's assumption of S-shaped growth. Next, a reduced fleet also resulted in a reduction in industry employment of 78 persons (or 28%). However, as in the original policy strategy, such a decrease in fleet size and employment has a positive financial effect for the remaining industry. Moreover, (1) total industry value increased by an additional 15.88M euro (or 3%), (2) average industry value per vessel increased by 1.53M euro (or 31%) and (3) average wages increased by 22120 euro (or 29%) compared to the original policy strategy. Finally, the additional increase in total industry value (15.88M euro) needs to be compared to the additional increase in government expenses, which is 17.26M euro. Consequently, additional government expenses are 1.38M euro more than the additional industry value. Given the earlier findings on the relationship between decommissioning fees and total industry value, this ratio was not expected. It can be explained by the (almost) total buy-out of the large beam trawler fleet and small beam trawler fleet, in which decommissioning fees were equal to the remaining value of these vessels. In sum, eliminating large beam trawlers and small beam trawlers results in a smaller, more ecological fleet at higher additional government expenses and is not fully compensated for by the increase in industry value. However, this compensation is not that important for SWF4. These findings are in line with the findings from the similar scenario of SWF2, with the difference that here the additional government expenses were not generously compensated for by additional industry value.

Figure 4.13: Outcomes for "total industry value" (€) and "government expenses" (€) for the different policy strategies (i.e., scenarios) to meet social welfare function 4 ("Let's go green")



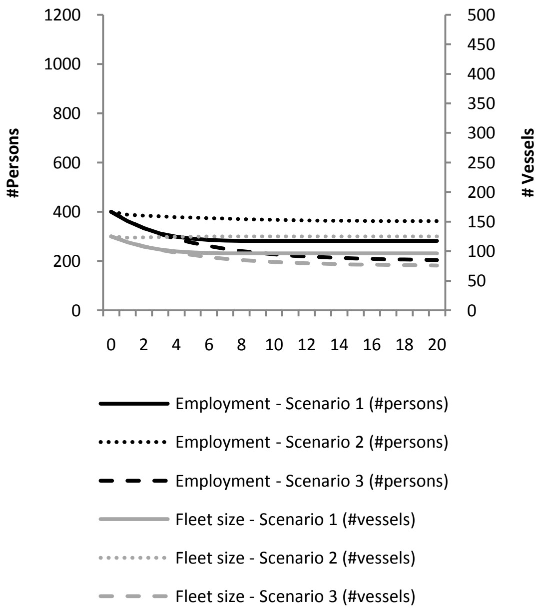
(Source: Own compilation)

Figure 4.14: Outcomes for "total industry value per vessel" (€) for the different policy strategies (i.e., scenarios) to meet social welfare function 4 ("Let's go green")



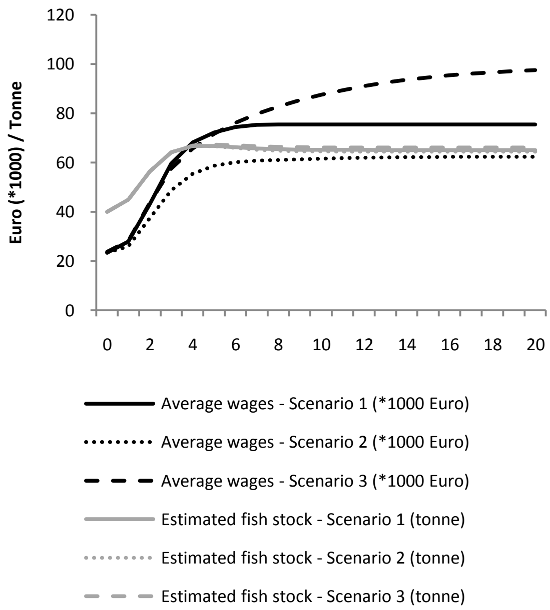
(Source: Own compilation)

Figure 4.15: Outcomes for "employment" and "fleet size" for the different policy strategies (i.e., scenarios) to meet social welfare function 4 ("Let's go green")



(Source: Own compilation)

Figure 4.16: Outcomes for "average wages" and "estimated fish stock" for the different policy strategies (i.e., scenarios) to meet social welfare function 4 ("Let's go green")



(Source: Own compilation)

Table 4.5: Overview of the results for the different scenarios aiming at meeting social welfare function 4 ("Let's go green!") ("SWF" = "Social Welfare Function"; "LBT" = "Large Beam Trawler"; and "SBT" = "Small Beam Trawler")

SWF4: LET'S GO GREEN!

Management objectives[a]:

Fleet size	-
Estimated fish stock	+

Scenario	Policy strategy	Outcome on management objectives[b]		Evaluation[c]
1	Quota = ½ recommended quota Quota unequally allocated over sub fleets in which 2/25 to LBT and SBT Unlimited fishing days Decommissioning fees = remaining value of vessel	Total industry value Industry value per vessel Fleet size Industry employment Average wages Government expenses Estimated fish stock	473M euro 4.91M euro 96 vessels 282 persons 75402 euro 37.97M euro 65.11 tonne	++
2	Quota = ½ recommended quota Quota unequally allocated over sub fleets in which 2/25 to LBT and SBT Unlimited fishing days	Total industry value Industry value per vessel Fleet size Industry employment Average wages Government expenses Estimated fish stock	419M euro 3.35M euro 125 vessels 362 persons 62331 euro 0 euro 64.42 tonne	+
3	Quota = ½ recommended quota Quota unequally allocated over sub fleets in which nothing to LBT and SBT Unlimited fishing days Decommissioning fees = remaining value of vessel	Total industry value Industry value per vessel Fleet size Industry employment Average wages Government expenses Estimated fish stock	489M euro 6.44M euro 76 vessels 204 persons 97518 euro 55.23M euro 66.04 tonne	+++

a: where "+" means "as high as possible"; "-" means "as low as possible"; and "=" means "keep at least constant compared to the previous year".
b: by the end of the 20 years of simulation time
c: range from "+++" meaning "very good policy strategy" to "---" meaning "very bad policy strategy".

4.4 Discussion

The answer to the research question "do policymakers have the policy instruments at hand to align the real fisheries world with their desired fisheries world (i.e., the social welfare functions)?" is affirmative. This study illustrates, through running multiple scenarios in our microworld, that policymakers in Belgian fisheries currently have the policy instruments at hand to install management systems that are able to meet four realistic but totally different social welfare functions. It is important to note that our microworld's aim is not to assess exactly what the impact is of a certain management system on the fisheries system. Instead, the goal is more to illustrate the dynamic complexity between the fisheries system and the fisheries management system. Additionally, the microworld also illustrates how the omission of certain policy instruments from the management system can often have devastating results. Hence, the right combination of policy instruments must be found to maximise the preferred social welfare function. However, this study has also vividly illustrated that counterintuitive outcomes can emerge from these mixtures of policy instruments (i.e., management systems). Counterintuitive behaviour of the fisheries system happened frequently and "reveals flaws and blind spots in people's thinking" (Morecroft, 2008: 82). These flaws and blind spots are caused by what is referred to as "misperception of feedback" (Atkins *et al.*, 2002; Diehl *et al.*, 1995; Sterman, 1989); the apparent inability to see the feedback at work in systems (Ford, 1999). This occurs when people's mental models are deficient in understanding the dynamic complexity of the system they are trying to manage (Sterman, 2000). Such dynamic complexity (Senge, 1990) appears in systems consisting of many interlocking negative and positive feedback loops in combination with time delays, which generates nonlinear and delayed system behaviour. Since fisheries systems are dynamically complex, it is therefore not surprising that misperception of feedback occurs when managing fisheries. This has also been confirmed by other studies on managing fisheries systems or natural resource management in general (Moxnes, 1998a, 1998b; Stouten *et al.*, 2008).

This study also illustrated the interdependency and often conflicting nature of management objectives. Mardle and Pascoe (2002a: 50) state that "generally, the major conflict for management occurs between the attempts to conserve the stocks and the desire for policymakers to satisfy the needs of the fishing community with respect to jobs and income". However, this study has also visualised the existence of the other trade-offs such as the trade-offs between (1) industry employment and average wages and (2) fleet size and average industry value per vessel. As such, like in all feedback systems, conflicts and trade-offs are proven to be inherent to the nature of the fisheries system (Richardson *et al.*, 1999). Consequently, this study concludes that if policymakers consider the interdependencies between objectives when defining their desired social welfare function, they mostly do have the policy instruments at hand to actually meet them. This statement has one important problem: the assumption that policymakers actually define the social welfare functions before implementing a management system. According to Pope (1997), this is not the case. He states that "a key deficiency in policy statements is that they do not set priorities or trade-offs between the various objectives nor do they set measurable targets for individual objectives" (Pope, 1997). A similar statement has been made by Degnbol (2009), a member of the Directorate-General of Maritime Affaires and Fisheries of the European Commission, about the CFP: "the CFP objectives are not focused and prioritized". Future research should therefore determine to what extent fisheries management prioritises its management objectives. A good starting point is already given by Pascoe's et al. (2009) for Australia.

This study also sheds a different light on the effectiveness of fisheries management, albeit indirectly. The lessons learned from this study reveal that the assessment of the effectiveness of fisheries management depends on one's belief of what the real management objectives are. In strategic management, Mintzberg (1978) pointed out that there is often a huge difference between a firm's intended and realised strategy, which roughly corresponds to differences found between respectively a firm's written and unwritten strategy. This distinction can also be made with regard to public policy strategies. For instance, if one believes that the written management objectives of the CFP (i.e., predominantly MSY) are its "real" objectives, then it is perhaps fair to say that the CFP is not hugely effective. The EU itself has even acknowledged this in its "green papers" (EC, 2001, 2009). However, a few studies (e.g., Boude *et al.*, 2001) state that the CFP's most predominant management objective is the unwritten objective of preserving social peace. If one looks through this lens, then it is perhaps fair to say that the CFP is actually rather effective. Although social peace is never stated officially as a management objective, studies have often considered it as a highly important unwritten management objective, if not the primary objective of fisheries policymakers (Hilborn, 2007a; Mardle *et al.*, 2002b; Mesnil, 2008; Stouten *et al.*, 2008). Such unwritten objectives, in combination with highly politicised fisheries management processes (Hilborn, 2007a), can often explain "irrational" fisheries management decisions. One of the most famous "irrational" policies is continuing to subsidise fisheries, even though studies have highlighted governmental subsides as a primary cause of overcapacity and overfishing (Mesnil, 2008). One can view this as a political process gone wrong, one which attempts to reduce the whining from the sectors being subsidised (Hilborn, 2007a: 155). When evaluating the outcome of the effectiveness of a fisheries management system and the rationale behind the use of policy instruments, it is thus essential to choose an objective function which you accept as the real social welfare function the fisheries policymakers are trying to meet.

Finally, the ultimate goal of modelling studies is the application of their insights to the real world. One hopes that microworlds will assist people to manage some activities better in the future (Richardson *et al.*, 1999). Consequently, the results of this study must be translated into practical suggestions for policymakers to improve fisheries management. However, since this study is based on a theoretical microworld, the practical suggestion will be limited to general guidelines for improving fisheries management. First and most importantly, policymakers should start focusing and prioritising their management objectives (if this is indeed not yet done). If social peace is a priority, then it should be written down, instead of remaining unwritten. This would allow evaluation research to include this objective in their assessments of the effectiveness of the applied fisheries policy strategy. If social peace is not officially stated as an important management objective, policymakers should start adopting a management system that is effective and efficient in the light of the agreed social welfare function, even if it affects the social peace of the (fishing) community. This is a difficult strategic exercise. It requires political courage and visionary leadership. Second, policymakers need to be aware of misperceptions of feedback when installing or altering a fisheries management system. This clearly points to a future role for microworlds or learning laboratories in advising fisheries policymakers, even though this advice will not take the form of concrete answers to concrete problems. The advice will rather unveil the dynamical complexity of the fisheries system and prepare policymakers for alternative futures by bringing these futures to life in a way that is not otherwise possible. Moreover, such microworlds not only help fisheries policymakers to generate alternative futures but also change and enrich their interpretation of a complex world (Morecroft, 2008: 6). In sum, they will serve the purpose of visualising and rehearsing policy strategy (Morecroft, 1999) bringing them into debate and discussion (Morecroft, 1984). A final practical suggestion for policymakers to improve fisheries management is to find the right combination of policy instruments in order to best meet their desired social welfare function. Consequently and as a matter of general principle, this study, like the study of Greiner *et al.* (2000), also puts forth that it is very unlikely for one single policy instrument to be capable of solving a complex problem. Microworlds can play a crucial role in finding the right mixture of policy instruments to achieve the desired social welfare function.

4.5 Conclusion

Through use of a microworld or learning laboratory, this study illustrates that policymakers usually have the policy instruments at hand to meet their desired social welfare functions, but only when those functions take into account the interdependencies between objectives. As a result, the research question of whether policymakers have the policy instruments at hand to align the real fisheries world with their desired fisheries world (i.e., the social welfare functions) can be answered in the affirmative. Nevertheless, policymakers should be careful when implementing these management systems, as counterintuitive (surprising) outcomes may occur due to "misperceptions of feedback". This conclusion has one significant problem: the assumption that policymakers define social welfare functions before implementing a management system. Doubt remains about to what extent fisheries policymakers truly prioritise their management objectives. Further, this study sheds a different light on the assessment of the effectiveness of fisheries management systems and the rationale behind the use of policy instruments. It concludes, albeit indirectly, that this assessment depends on which objective function one accepts as the real social welfare function the fisheries policymakers are trying to meet. Discovering unwritten objectives and hidden agendas, which are often the rationale behind seemingly irrational policy strategies, can shed new light on the effectiveness of fisheries management systems.

Since the ultimate goal of modelling studies is to apply their insights to the real world, this study formulates general guidelines for improving fisheries management. First and most important, policymakers should start by focusing and prioritising their management objectives (if they haven't already). Only after setting these priorities and agreeing on a social welfare function can policymakers adopt a management system that is effective and efficient in the light of the given social welfare function. Second, policymakers need to be aware of the abovementioned problem of misperceptions of feedback when installing or altering a fisheries management system. These findings indicate a certain future role for microworlds or learning laboratories in advising fisheries policymakers, even though this advice does not provide concrete answers to concrete problems. Microworlds or learning laboratories will serve the purpose of visualising and rehearsing policy strategies, bringing them into debate and discussion. Finally, since it is very unlikely for one single policy instrument to be capable of solving a complex problem, policymakers should determine the right mixture of policy instruments to achieve their desired social welfare function. Future research should work at facilitating these "tasks" for fisheries policymakers. This should be done mainly by (1) defining a framework/methodology for prioritising fisheries management objectives; and (2) developing a broader range of microworlds that include different mixtures of policy instruments, including policy instruments outside the scope of our microworld, to see how those instruments interact with different fisheries systems in service of different desired social welfare functions.

PART II: LEARNING FROM THE MICROWORLD

Photo: Ir. Jochen Depestele is leading the experimental condition of my experiment
(©Annemie Schollaert - ILVO)


Jaar
Groen = 20000
Geel = 10000
Rood = -30000
4

Chapter 5: Stakeholder learning from microworlds

5.1 Introduction

Microworlds, as a specific form of simulation models, are in many fields often referred to as: (1) insight generators (Morecroft, 1984), (2) tools for inquiry into dynamic decision-making processes (Brehmer, 2005; Gonzalez *et al.*, 2005), (3) tools to visualise and rehearse decisions and strategies (Morecroft, 1999; Morecroft, 1984), (4) tools to debate and discuss strategies (Morecroft, 1999; Morecroft, 1984), (5) laboratories for ex ante evaluation of decision-making (De Geus, 1997; Keys *et al.*, 1996), (6) learning laboratories (Kim, 1993b; Romme *et al.*, 1997), (7) learning environments (Wolfe, 1976), (8) learning spaces (Senge, 1996), and (9) educational tools (Sindre *et al.*, 2009). In other words, various scientists believe, explicitly or implicitly, that some form of "learning" occurs when using microworlds. Nevertheless, this belief still generates widespread disagreement within several scientific communities (Bakken *et al.*, 1994; Bell *et al.*, 2008; Cavaleri *et al.*, 1996; Langley, 1993; Langley *et al.*, 1996). The main reason for this disagreement is the continued absence of a well-structured body of evaluation research that systematically examines whether any valuable learning takes place from the use of microworlds (Akili, 2007; Bakken *et al.*, 1994; Bell *et al.*, 2008; Cavaleri *et al.*, 1997; Gosen *et al.*, 2004; Gresse von Wangenheim *et al.*, 2009; Huz *et al.*, 1997; Raia, 1966; Sweeney *et al.*, 2000; Tonks *et al.*, 1997; Wolfe, 1976). There is no justified reason for this lack of evaluation research. This study aims to remedy this situation.

Up to the beginning of the 1990s, with few exceptions (e.g.: McKenney, 1962, 1963; Raia, 1966), this research question remained the province of anecdotes, reactions, impressions and opinions rather than rigorous research (Cavaleri *et al.*, 1997; Wolfe *et al.*, 1975). Impressions and opinions do have value, but Raia (1966: 340) had already stated in the 1960s that "a survey of the literature reveals a continuing need to improve research methodology and design …*[since]*… there have been few attempts to properly control some of the more significant variables in the environment". He also said, "there is a need to appraise the effectiveness of games *[i.e., microworlds]* in terms of more objective criteria. These might include measures of knowledge, skills, attitudes, and levels of interest and motivation" (Raia, 1966: 341). From the 1990s onwards, improvement in the research methodology and design was mainly addressed through applying "controlled" experimental designs (Huz *et al.*, 1997). But the control in these designs was often lamentable, leaving room for many alternative explanations (Akili, 2007; Gresse von Wangenheim *et al.*, 2009). In fact, some studies were only applying quasi-experiments since they (1) lacked a control group (e.g.: Cavaleri *et al.*, 1997; Dill *et al.*, 1963; Hung, 2008) or (2) the random assignment of the subjects to experimental treatments could be questioned (e.g.: Wolfe *et al.*, 1975). Others who did attempt to use a true experimental design often lacked other forms of control or a strict "before-after" research design (e.g.: Hancock *et al.*, 1961; McKenney *et al.*, 1966). Such before-after research design is necessary because, even if participants are randomly assigned to groups, one group may well perform better than the other (especially with the small sample sizes often found in this kind of evaluation research) (Sindre *et al.*, 2009). Administering a pre-test before the learning intervention controls for this effect (Sindre *et al.*, 2009).

However, evaluation studies need more than well-controlled true experimental designs to tackle the research question of whether any valuable learning takes place from the use of microworlds. For instance, these true experiments may attempt to address research questions that are methodologically impossible to answer. The best-known illustrations of this error are the vast number of studies (e.g.: Franz *et al.*, 1992; McKenney, 1962, 1963; Moore, 1967; Raia, 1966; Shields, 1999, 2001; Wolfe, 1975b; Wolfe *et al.*, 1975) that have tried to compare the (relative) effectiveness and efficiency of microworlds to other learning and training tools, usually conventional paper case studies (Clark, 1983). However, the (relative) effectiveness and the efficiency of microworlds in comparison to other training methods can hardly be measured. This is because the methods under observation consist of a sample of characteristics which can be varied in essentially infinite ways (Clark, 1983; Stolurow, 1962). Because of this, such comparisons have nearly died out (Größler, 2001; Weidenmann, 1993). This type of error is mainly due to the absence of a broadly-supported objective evaluation framework (based on objective evaluation criteria for learning from microworlds) and uniform methodology (Carvalho, 1991; Feinstein *et al.*, 2001, 2002; Gentry *et al.*, 1998; Keys *et al.*, 1990).

Several problems exist when developing an objective evaluation framework and uniform methodology for the case of learning from microworlds. The trouble begins with the very definition of “learning” (Gentry *et al.*, 1998; Keys *et al.*, 1990). Many studies (e.g.: Anderson *et al.*, 1992; Hancock *et al.*, 1961) conceptualised “learning” as improvement in controlling the microworld and improving “game performance” (i.e., better performing in the microworld) (Faria, 2001; Gosen *et al.*, 2004; Warren *et al.*, 1999). As a result, these studies assumed that the higher the score on the performance measures in the microworld, the more has been learned about how the microworld works and therefore how the real world works. These studies assumed that improved “game performance” results in improved performance in similar real-life situations. However, the capability of microworlds to stimulate a learning transfer has not yet been confirmed (Größler, 2001). Moreover, studies have even shown that these assumptions do not always hold the truth (Anderson *et al.*, 1992; Bakken, 1993; Diehl, 1992; Thorngate *et al.*, 1987; Washbush *et al.*, 2001; Wellington *et al.*, 1992). In addition, the microworld in these experimental studies also serves a double function: it is the treatment as well as a means to measure the results of the treatment. As a result, further methodological problems can occur and have not yet been widely discussed (Funke, 1993; Größler, 2001). For these reasons, studies abandoned the use of “game performance” as the only measure of learning. Instead, game performance became included in a broader evaluation framework (Faria, 2001; Gosen *et al.*, 2004). Huz *et al.* (1997) developed a highly interesting (albeit broad) framework. It is built along three levels of deepening analysis, being: (1) formal or informal reflections on the modelling intervention (Level 1), (2) participant’s self-reporting of intervention impact on his or her attitudes, beliefs, and actions (i.e., behaviour) (Level 2), and

(3) measurement of actual system change (Level 3). Similarly, Gröβler (2001) presented a working definition of learning that can also serve as an evaluation framework since it includes "two processes and the result of these processes, being: (1) a change in cognitive structure *[knowledge]*, and (2) a change in behavior, which lead to (3) a change in performance" (Größler, 2001: 5). Although these frameworks consist of valuable and objective evaluation criteria for learning from microworlds, they have barely been used in empirical research.

With only few exceptions (e.g.: Cavaleri *et al.*, 1997; Huz *et al.*, 1997), a final frequently occurring methodological shortcoming is that most studies use students (e.g., college students (Hancock *et al.*, 1961), undergraduate students (Brekke *et al.*, 2003; Gresse von Wangenheim *et al.*, 2009; Pala *et al.*, 2005; Pfahl *et al.*, 2001), MBA students (McKenney, 1962, 1963; Moffie *et al.*, 1968; Starbuck *et al.*, 1966), graduate students enrolled in other educational programs (Hung, 2008; Pfahl *et al.*, 2004; Sweeney *et al.*, 2000; Wolfe, 1975a, 1975b; Wolfe *et al.*, 1975) and/or faculty staff (Raia, 1966) as subjects in their studies. The conclusions about learning from microworlds from these studies are therefore limited in their applicability to decision makers like managers or public policymakers (Burns *et al.*, 1990). These studies used students mostly out of practical reasons, namely: university-based participants are easier to target, there is a possibility of high participation rates, and costs are lower (Brekke *et al.*, 2003). While previous experiments indicated that there are reasons to expect that differences between students and actual decision makers could be small and insignificant (Bakken *et al.*, 1994; Moxnes, 1998a), there remains doubts to whether this jeopardises the external validity of these studies (Bell *et al.*, 2008; Brekke *et al.*, 2003; Burns *et al.*, 1990).

The aim of this study is to contribute to the inquiry of whether any valuable learning takes place from the use of microworlds. We have made an effort to overcome these methodological problems or at least address them. This study examines if actual decision makers learn from using microworlds. The scope of this study is the Belgian fishing industry. The objective is to determine whether stakeholders learn from a microworld used to gain insight into the long-term effect of policy instruments on the Belgian fisheries system. Three stakeholder groups (i.e., policymakers, scientists and ship owners and skippers) were tested using a "before-after with control group"-experiment. We tested the influence this microworld had on their subjective knowledge about the most common policy instruments in Belgian fisheries, as well as their attitude toward them and their behavioural intention in relation to these instruments. In addition, this study also examines their attitude towards the microworld used as well as their perceived internal validity of the microworld. Last, it examines whether stakeholders reported differences in learning from the microworld about (1) the impact policy instruments have on fisheries systems, and (2) how difficult it is to manage fishery systems. All these learning criteria were drawn from the suggested frameworks of Huz *et al.* (1997) and Gröβler (2001) and applied to the case of Belgian fisheries. An examination of this study in light of Huz *et al.*'s (1997) evaluation framework reveals that this study captures formal reflections on the modelling intervention (Level 1) and participants' self-reporting impacts of the intervention on their attitudes, behavioural intentions and behavioural expectations (Level 2). However, this study does not aim to measure changes in actual behaviour and system changes (Level 3), because that would require a longitudinal study. Such longitudinal studies are subject to an enormous number of methodological and ethical problems that often lead to questionable results and outcomes (Größler, 2001). To compensate for the shortcoming of not measuring actual behaviour and system changes, this study uses the theory of planned behaviour (Ajzen, 1991; Hardeman *et al.*, 2002) for approximating future behaviour through measuring behavioural-intentions-and-expectations (Gibbons, 2009). Gröβler's (2001) working definition is taken into account since this study also assesses the influence of microworlds on the participants' knowledge. This is done through measuring changes in participants' subjective knowledge, a worthy surrogate for objective knowledge (Carlson *et al.*, 2009). Subjective knowledge is chosen because it can be easily measured through a short and reliable self-reported measure (Flynn *et al.*, 1999).

This study contains four sections. Section 1, Materials and Methods, describes the microworld, which this study uses as the experimental condition. The population, sample and recruitment of the stakeholder groups are then given. A detailed overview of the experiment follows, which presents (1) the before-after with control group design, (2) the pre-and post-test questionnaires, and (3) the experimental procedure. The hypotheses are then presented, based on the objectives and experimental procedure. The section concludes with the method of data analysis. Section 2 contains the results of the experiment which clearly indicate that using the microworld did not result in changes in the participants' subjective knowledge, attitude and behavioural intention towards commonly used policy instruments in Belgian fisheries management. In contrast, all stakeholders groups reported that they had learned from the microworld about the effect policy instruments have on the fisheries system and that they had confidence in the microworld and perceived its behaviour as valid. Section 3 discusses these contradictory results and provides possible explanations for these findings. It also discusses the limitations of this study. Section 4 presents the conclusions.

5.2 Materials and Methods

5.2.1 The microworld: the experimental condition

The microworld used in this research is called the "Belgian Fisheries Microworld" (Stouten, 2009). It based on a system dynamics simulation model and allows stakeholders to "play" and gain long-term insight into the effect policy instruments have on the Belgian fisheries system. The approach is a game run in a dynamic decision-making mode (Langley *et al.*, 1996; McCormack *et al.*, 1998; Wolfe, 1975a) where the players of the microworld can alter policy instruments each year. The story behind the game is that the player is the only policymaker in Belgian fisheries and needs to maximise votes for the upcoming elections. The player can use most of the Belgian policy instruments to formulate his or her policy strategy: (1) total quota, (2) the allocation of the total quota over Belgium's five sub fleets, (3) maximum fishing days per vessel, (4) maximum catch per fishing day, (5) licences, (6) decommissioning fees, (7) investment subsidies, and (8) fuel subsidies and taxes. After having formulated a policy strategy, the collective group of stakeholders then vote in function of how well the player paid attention to their needs, as captured by (1) total industry value, (2) industry value per vessel, (3) fleet size, (4) industry employment, (5) average wages, (6) government expenses, and (7) estimated fish stock. The player's score on each of these objectives is indicated by "status lamps". A green light means "doing very well" and the player gains 20000 votes, yellow light means "can do better" but the player still gains 10000 votes and red means "highly neglecting this objective" and the players loses 30000 votes. The total number of votes is simply the sum of the votes for each of these seven objectives. The more votes the player obtains, the higher the score and the higher the chance of being re-elected. For further information and full details about the development and architecture of this microworld, see Chapter 3 above.

5.2.2 The stakeholders: population, sample and recruitment

This study invited three groups of stakeholders in the Belgian fisheries to participate on a voluntary basis in our experiment. They were: (1) policymakers, (2) scientists and (3) ship owners and skippers. Policymakers, involved directly or indirectly in the Belgian fisheries, were invited via post from (1) the Department of Agriculture and Fisheries of the Flemish Government, (2) the Cabinet of the Flemish Government for Sea Fisheries, (3) DG Maritime Affairs and Fisheries of the European Commission, and (4) the Cabinet of EU Commissioner Joe Borg. The experiment's designer also called each member of the DG Maritime Affairs and Fisheries and the Cabinet of EU Commissioner Joe Borg in an attempt to increase their participation rate. Fisheries scientists were defined as all employees of the Institute of Agricultural and Fisheries Research (ILVO) whose wage scale equals that of a scientist. These scientists were invited via e-mail with a follow-up visit from the experiment's designer. Representatives of the fishing industry were limited to ship owners and skippers as they have principal responsibility for running the fishing industry according to regulations. Each shipping company (based on the "Fisheries Yearbook 2009" (Pronk, 2009)) received a letter inviting their ship owners and skippers to participate in the experiment. In addition, advertisements (i.e., posters and flyers) were placed in fish auctions, pubs, and administrative authorities that ship owners or skippers often visit. Whenever a vessel was stationed in a Belgian port, the experiment's designer visited and invited those ship owners and skippers. They were also recruited via phone calls to every shipping company that operates a Belgian vessel.

Table 5.1 illustrates the (1) population, (2) sample (the number of actual participants), and (3) participant rate for each of the organisations of these stakeholder groups. It shows that policymakers at the national level were well represented (i.e., 81% and 67%), but those at the European level were less eager to participate (i.e., 9% and 0%). These low participation rates at the European level were expected since these policymakers are highly inaccessible. The participation rate of the scientists was high, given that five scientists were excluded from participation because they have served as the scientific expert group who helped with design of the microworld. Inviting them would have biased the results of this study because of their knowledge of the microworld prior to the experiment. Ship owners and skippers were less well represented. This was as expected since they are difficult to target, especially when it concerns scientific research involving computers and simulation.

Table 5.1: Overview of population, participants and participation rate by stakeholder group

Stakeholdergroup	Organisation	Population*	Participants	Part. rate
Policymakers	The Department of Agriculture and Fisheries of the Flemish Government	21	17	81%
	The Cabinet of the Flemish Government in charge of sea fisheries	3	2	67%
	DG Maritime Affairs and Fisheries of the EU	69	6	9%
	Cabinet of Commissioner Joe Borg	13	0	0%
Scientists	Institute of Agricultural and Fisheries Research (ILVO)	35	20	57%
Fishing industry	Ship owners and skippers	(Unknown)	12	

*This is an approximation of the population; it consists only of the people who are involved directly or indirectly in Belgian fisheries.

(Source: Own compilation)

5.2.3 The experiment: before-after with control group design

The experiment was held during five consecutive sessions (daily from 14:00 to 17:00 on 29 June - 3 July 2009) in two almost identical but separate PC-rooms at the "IOC Project Office for IODE" at Ostend, Belgium (Table 5.2). Each of these sessions was designed as a "before-after with control group"-design (Christensen, 1997: 339) (Table 5.3). This design makes it possible to assess the effect a microworld has on (1) subjective knowledge, (2) attitude, and (3) behavioural intention through the comparison of pre- and post tests. Additionally, the post-test allows for comparison of the stakeholder's attitude towards the microworld as well as his or her perceived internal validity of the microworld. It also shows whether stakeholders have reported differences in learning from the microworld about (1) the impact policy instruments have on fisheries systems, and (2) how difficult it is to manage fishery systems. Finally, such a design does an excellent job of controlling for rival hypotheses such as history, maturation and instrumentation variables, although intra-group differences could still exist (Christensen, 1997). This design is also the most recommended for assessing learning from microworlds (Cohen *et al.*, 2000; Größler, 2001). Many similar studies have also used this design (e.g.: Drappa *et al.*, 2000; Gresse von Wangenheim *et al.*, 2009; Huz *et al.*, 1997; Pala *et al.*, 2005; Pfahl *et al.*, 2001; Pfahl *et al.*, 2004; Raia, 1966; Sindre *et al.*, 2009; Wolfe *et al.*, 1975). Participants were randomly assigned to a computer in the experimental or control group, which controlled for regression and selection variables. Each participant got his or her own computer showing the microworld. In order to eliminate peer interaction, we left one seat free between participants whenever possible. In addition, participants were requested to remain seated for the duration of the experiment. These measures assure that all participants received the same treatment.

Participant effects (and especially demand effects, positive self-presentation and the Hawthorn effect (Christensen, 1997)) were controlled since the experiment was “disguised” (Christensen, 1997: 294). Participants were told they would participate in a gaming competition in which they needed to manage the Belgian fisheries through using the microworld to the best of their ability. But this competitive setting was a deception (Christensen, 1997: 292) that was enforced by administering a valuable prize (one iPod Touch 8GB) to the winner of each group. This prize also motivated the subjects to (1) participate in the research, (2) take the exercise seriously, (3) reduce trial-and-error gaming, and (4) learn from the microworld (Camerer *et al.*, 1999; Starbuck *et al.*, 1966; Wolfe, 1976). Next, the organisation of the sessions reduced demand characteristics such as rumours among subsequent sessions as (1) participants of the same organisation almost always participated in the same session, eliminating “intra-organisation” rumours; and (2) sessions were organised only once per day, eliminating direct contact between participants before and after each session. Experimenter effects were controlled by using the “partially blind technique” (Christensen, 1997: 302) since the experimenters knew only the experimental condition the subjects were in when the subjects took place in the two PC-rooms. Next, the time between the pre-and post-test was kept the same for both experimental and control group, since the participants of the control group were occupied with another task while the experimental groups played with the microworld. The control group spent their time learning about strategic groups in Belgian fisheries, a subject that was far enough removed from the objective of the experiment that it would not interfere in the post-test. Finally, three experimenters performed the experiment over the five sessions. The designer of the experiment (a male junior fisheries scientist) led the control group during all five sessions. The experimental group was led in the first three sessions by a male junior fisheries scientist and in the last two by a male senior fisheries scientist, all employees of ILVO. As a result, this study tried to control the experimenter attributes (Christensen, 1997: 247) by matching the three experimenters as much as possible qua gender, age and appearance.

Table 5.2: The five sessions of the experiment

Session	Day	Date	Stakeholder group	Organisations	Language
1	Mon	June 29th, 2009	Policymakers	1) The Department of Agriculture and Fisheries of the Flemish Government 2) The Cabinet of the Flemish Government for Sea Fisheries	Dutch
2	Tue	June 30st, 2009	Fishing industry	Ship owners and skippers	Dutch
3	Wed	July 1st, 2009	Scientists	Institute of Agricultural and Fisheries Research (ILVO)	Dutch
4	Thu	July 2nd, 2009	Fishing industry	Ship owners and skippers	Dutch
5	Fri	July 3th, 2009	Policymakers	1) DG Maritime Affairs and Fisheries of the EC 2) Cabinet of EU Commissioner Joe Borg	English

(Source: Own compilation)

Table 5.3: “Before-after with control group”-design for each session

SESSION (≈ STAKEHOLDER GROUP)	
Experimental group*	Control group*
Pre-test	Pre-test
Play to learn for gaming competition	
Post-test	Post-test
Gaming competition	Gaming competition

* Participants were randomly assigned to experimental and control group
(Source: Own compilation)

5.2.4 The pre-and post-test: the questionnaires

Both pre-and post-tests in this study were questionnaires. Development of these questionnaires started with a preliminary questionnaire that aimed to identify (1) subjective knowledge of commonly used policy instruments in Belgian fisheries and (2) attitude toward them and (3) behavioural intention in relation to these instruments. The questionnaires also included two possible covariates: (1) their attitude toward computers (ACOMP) and (2) their attitude toward computer simulation models (ACSM) were also included. The inclusion of covariates is common practice in questionnaires for evaluation research, especially the measurement of subject’s belief in microworlds (e.g.: Brekke *et al.*, 2003). This questionnaire was anonymous but included a few personal characteristics like gender, age and work. “Subjective knowledge” was measured by Flynn’s and Goldsmith’s (1999) short and reliable self-reported measure of subjective knowledge. It consisted of five prepositions and employed a seven point Likert-type response format. “Attitude towards policy instruments” was measured through a direct measure that identified the attitude toward each of the policy instruments (included in the microworld) individually by means of a semantic differential (Raia, 1966). Each of these semantic differentials consist of exactly the same four pairs of bipolar adjectives which were based on Francis *et al.’s* (2004) “manual for constructing questionnaires based on the theory of planned behaviour”. The four bipolar adjectives included both instrumental items (whether the behaviour achieves something; e.g., *harmful-beneficial*) and experiential items (how it feels to perform the behaviour; e.g. *fair – unfair*) and were all based on a seven point Likert scale. “Behavioural intentions toward policy instruments” can be measured following three methods: (1) intention performance, (2) generalised intention, and (3) intention simulation (Francis *et al.*, 2004). In this study, the “intention performance”-measure was not suitable because it refers to how many time a subject intends to perform a behaviour in a certain amount of time or number of cases. The “intention simulation”-measure was assumed to be much too demanding for the subjects of some of our stakeholder groups. It also would have significantly increased the length of the questionnaire. Consequently, we opted for the most commonly used method, “generalised intention”. Finally, Shaft, Sharfman and Wu’s (2004) “attitude towards computers instrument (ATCI)”-measure was used to measure both “attitude toward computers” and “attitude toward computer simulation models” with the only difference that for measuring the „attitude toward simulation models' the term „computer' was replaced by „computer simulation model' in the ATCI-measure.

The preliminary questionnaire was developed in order to find out if it would pass some important reliability tests. The questionnaire passed through three stages of testing. First, a small "expert panel" (Czaja, 1998: 59) from ILVO reviewed the questionnaire. This panel consisted of (1) the designer of the questionnaire, a junior fisheries scientists involved with fisheries management issues, (2) a senior fisheries scientist with knowledge of questionnaire design, and (3) a senior fisheries scientist and coordinator of Belgium's research group on fishing technology. Second, "cognitive interviews" (Czaja, 1998: 58) were conducted one-on-one between the designer of the questionnaire and four respondents from ILVO. Unfortunately, we could not conduct cognitive interviews with subjects of the study's target population without heavily jeopardising the study itself, given the limited number of individuals in each stakeholder group. Interviews with four technicians from ILVO proved to be a suitable substitute, as these technicians are as familiar with the effect policy instruments have on the Belgian fisheries system as most members of the population. Third, a "field pretesting" (Czaja, 1998: 60) was held by administering the questionnaire to 15 technicians and/or laboratory assistants of ILVO. The aim of this "field pretesting" was to estimate the reliability and internal consistency of the questionnaire through (1) the "Test/retest" method (Raia, 1966: 344), and (2) calculating the Cronbach's Alpha for each construct. Due to the results of these different tests, the preliminary questionnaire became the pre-test questionnaire (Appendix 1 and 2), with the only difference that behavioural intention is now measured through (1) behavioural intention and (2) behavioural expectations (Gibbons, 2009).

The post-test questionnaire for the control group differs from the pre-test questionnaire in four ways (Appendix 3 and 4). First, it does not double-check the subject's demographic characteristics, attitudes toward computers and computer simulation models, since these are already known from the pre-test. Second, similar questions to the pre-test were extended with legitimating that the respondent were allowed to alter his or her opinion as compared to the pre-test. Third, the order in which the prepositions or bipolar adjectives were given was often changed. Last, this questionnaire also allowed the subjects to make comments and/or suggestions about the proposed simulation model. The post-test questionnaire for the experimental group is the same as the post-test questionnaire for the control group, except that it is extended with measures of (1) the participants' attitude towards the microworld, (2) which policy instruments the participant had tested when playing with the microworld, (3) the validity of the microworld, and (4) learning from the microworld about both the effect policy instruments have on the fisheries system and about how difficult it is to manage a fisheries system.

These questionnaires were originally designed in English, since most of the scales used are based on or fully borrowed from peer-reviewed literature. To eliminate language errors, these questionnaires were reviewed by a native English speaker. However, since most stakeholders are native Dutch speakers, these questionnaires were translated to Dutch by the designer of the questionnaire (a native Dutch speaker). The Dutch translation was reviewed by a colleague at ILVO who is also a native Dutch speaker. Pilot-testing the questionnaire revealed some typos and language errors which were then corrected.

5.2.5 The experimental procedure

The experimental procedure is given in Table 5.4. On arrival, participants were welcomed and registered, and each participant received a personal file including (1) two identical numerical IDs, (2) a green or blue coloured paper, and (3) the business card of the experiment's designer. The two identical numerical IDs were used to protect the participant's privacy since these were used instead of names in coding and analysis (Sweeney *et al.*, 2000). One of the IDs was assigned to the computer and one was for the subject, making it possible to link a person to a computer. This was necessary when determining the group winners of the gaming competition. The coloured papers were used to randomly assign each participant to the experimental or control group (where "green" equalled "experimental group" and "blue" equalled "control group"). When all the participants had arrived, they were escorted at the same time to the two PC rooms, which were located next to each other. Before entering, participants were requested to look at their coloured paper in their personal file to know which room they were allocated to. After having entered the right room, the two groups were kept completely separate until the end of the experiment.

After participants had taken their place at the computer, the experimenter of both groups started by outlining the practical arrangements then administered the pre-test. After having filled out the pre-test, the subjects in the experimental group were introduced to the microworld and then spent 45 minutes intensively playing with the microworld. During that time, the subjects of the control group attended a lecture on strategic groups in Belgian fisheries. This subject matter was far enough removed from the objective of the experiment so it could not introduce undesired learning effects in the control group. Next, the post-tests were administered (as mentioned above, these questionnaires were not fully identical for both experimental and control group). Finally, a debriefing took place in each of the two groups that unveiled the true experimental nature and value of the study. During the entire procedure, the time slots reserved for completing a certain step of the schedule were identical for both the experimental and control group (Pfahl *et al.*, 2004). After the experiment was performed, the participants were escorted by the experimenters to a room with refreshments. This time for refreshments also gave the experiment's designer time to correctly determine the group winners.

Table 5.4: Procedure followed during each of the five sessions of the experiment (the dotted line indicates the physical separation between experimental and control group)

Time	Duration	Experimental group (green)	Control group (blue)
14:00 – 14:15	15'	Registration + random assignment of the subjects to the groups	
14:15 – 14:20	5'	Participants are escorted to the PC rooms	
14:20 – 14:25	5'	Practical arrangements	Practical arrangements
14:25 – 14:45	20'	Pre-test	Pre-test
14:45 – 15:00	15'	Introduction to microworld	Strategic group lecture
15:00 – 15:45	45'	Playing the microworld	Strategic group lecture (cont.) + Introduction to microworld
15:45 – 16:05	20'	Post-test	Post-test
16:05 – 16:35	30'	Gaming competition	Gaming competition
16:35 – 16:50	15'	Debriefing	Debriefing
16:50 – 17:00	10'	Participants are escorted to the reception	
17:00 – 17:30	30'	Reception + prize ceremony	

(Source: Own compilation)

5.2.6 Hypotheses

Based on the objectives of this study, the null hypotheses for this experiment are:

$H0_1$: There will be no differences in pre-test scores between the two treatment groups (i.e., the two randomly selected treatment groups will be equal).

$H0_2$: There will be no differences in pre-test scores between the different stakeholder groups (i.e., all stakeholder groups are initially the same related to the dependent variables).

$H0_3$: For the dependent variables that were measured in both experimental treatments, there will be no differences in the post-test scores between the two treatment groups (i.e., the two groups will (still) be equal after having played with the microworld).

$H0_4$: There will be no differences in post-test scores between the different stakeholder groups (i.e., all stakeholder groups are (still) the same related to the dependent variables after having played with the microworld).

$H0_5$: There will be no differences between pre- and post-test scores for the dependent variables that were measured in these two tests (i.e., both treatments caused no changes in subjective knowledge, attitude, and behavioural intention).

$H0_6$: The differences between the pre- and post-test scores on the dependent variables that were measured in both tests are the same for both treatment groups (i.e., the microworld caused no changes in subjective knowledge, attitude, and behavioural intention).

$H0_7$: The differences between the pre- and post-test scores for the dependent variables that were measured in both tests are the same for all stakeholder groups (i.e., stakeholder groups report the same changes in subjective knowledge, attitude, and behavioural intention independent from the treatment condition).

5.2.7 Method of data analysis

The data of the experiment are analysed in four steps. First, data of the "field pre-test" (i.e., the pilot-test) are analysed for its reliability. Second, pre-test data were analysed to check for initial differences between experimental and control group. This determines whether the random assignment of subjects to both experimental and control group has resulted in two initially "identical" groups in which all confounding variables are eliminated. Additionally, pre-test data are also analysed to shed light on the initial differences between stakeholder groups. Third, post-test data are analysed to determine the differences between stakeholder groups and experimental conditions after the experiment. Fourth, the differences between pre- and post-test are examined in order to determine changes due to the experiment in (1) subjective knowledge, (2) attitude and (3) behavioural intention towards commonly used policy instruments.

For the pilot data, (1) subjective knowledge, (2) attitude towards policy instruments, (3) behavioural intention towards policy instruments, (4) attitude towards computers and (5) attitude towards computer simulation models were all normally distributed in the "test" sample of the test-retest procedure (i.e., first sample) following both Kolmogorov-Smirnov D (with Lilliefors significant correction) and Shapiro-Wilk W tests, respectively. For the retest data, very similar results are obtained for the Kolmogorov-Smirnov D test (with Lilliefors significant correction). However, when the more powerful test of Shapiro-Wilk W is performed, attitude towards policy instruments is non-significant $(W(15)=0.85,\ p<0.05)$. Additionally, the variance is equal for all five variables when comparing the test to the retest data. As a result of these statistics, the test-retest reliability is assessed through paired sample t-tests on (1) subjective knowledge, (2) behavioural intention towards policy instruments, (3) attitude towards computers, and (4) attitude towards computer simulation models. Wilcoxon signed-rank test is used for attitude towards policy instruments since normality cannot be assumed. Next, the internal consistency is assessed through computing Cronbach's Alphas for each construct.

For the pre-test, this study visually inspects through crosstabs if the demographic characteristics for each stakeholder group is equal among experimental and control group. This study only allow visual inspections since chi-square cannot be calculated because some cells in this crosstab have expected counts less than five. Next, the correlations between each of the five constructs are investigated. Pearson's r is used on (1) subjective knowledge, (2) attitude towards policy instruments, (3) behavioural intention towards policy instruments, and (4) attitude towards computer simulation models since they are normally distributed. Kendall's tau is used for attitude toward computers since the K-S test is significant, *D(57)=0.13, p<.05*. Based on the outcome of these correlations and the theoretical evaluation frameworks of both Huz *et al.* (1997) and Größler (2001), we perform a factorial ANOVA on subjective knowledge to test if the mean scores are significantly different between experimental conditions and stakeholder groups. A factorial ANOVA is appropriate because homogeneity of variances is assumed *(F(5,51)=0.36, p=.88)* and there is only doubt whether subjective knowledge for policymakers in the experimental group is normally distributed since *D(13)=0.20, p=.15* but *W(13)=0.83, p<.05*. Hochberg's GT2 are used as *post hoc* tests because sample sizes differ. Next, attitude and behavioural intention towards policy instruments are analysed together through an MANOVA followed by separate (factorial) ANOVAs and Hochberg's GT2 *post hoc* tests. MANOVA is appropriate since (1) homogeneity of variances and (2) equality of covariance matrices *(F(15,5084)=0.97, p=.48)* are assumed and normality is only questioned for policymakers in the experimental condition since *W(13)=0.91, p=.24* contrasts *D(13)=0.24, p<.05*. Finally, the same procedure is used to conjointly analyse attitude towards computer and computer simulation models.

For the post-test data, the correlations between each of the seven constructs are first investigated to see (1) if correlations are similar to those found in the pre-test and (2) if multivariate or univariate data analysis techniques shall apply in further analysing the data. Pearson's r is used on (1) subjective knowledge, (2) attitude towards policy instruments, (3) behavioural intention towards policy instruments, (4) attitude towards the computer simulation model used and (5) perceived internal validity of the computer simulation model used, since they are all normally distributed. Kendall's tau is used for those who are not normally distributed: (1) learning about the effect policy instruments have on the fisheries system and (2) learning about how difficult it is to manage a fisheries system. Next, to analyse the subjective knowledge between stakeholder groups and experimental conditions, a factorial ANCOVA is first used with both ACOMP and ACSM as covariates. ANCOVA can be performed because (1) tests of normality were all non-significant and (2) homogeneity of variance is assumed *(F(5,51)=1.13, p=.36)*. In addition, these two covariates can be used since the assumptions of (1) independence of the covariate and treatment and (2) homogeneity of regression slopes are both met. The first assumption was already tested through the MANOVA on the pre-test data of attitude towards computers and computer simulation models. The second assumption is tested through looking at the "independent variable*covariate"-interactions, all four of which are non-significant. After running the factorial ANCOVA, the results illustrate a non-significant effect for each of the two covariates, *F(1,49)=0.01, p=.93* for ACOMP and *F(1,49)=0.19, p=.67* for ACSM. In addition, since each covariate absorbs one degree of freedom, this study excludes the covariates from the analysis. As a result, this study ends up with running a factorial ANOVA on the post-test data for subjective knowledge with stakeholder group and experimental condition as the independent variables.

To analyse the post-test data on the attitude and behavioural intentions toward policy instruments among stakeholder groups and experimental conditions, a MANCOVA is first performed with ACOMP as a covariates. In this MANCOVA, ACSM cannot be used as a covariate since the assumption of homogeneity of regression slopes is violated by the significant interaction between stakeholder group and ACSM *(Pillai's trace, V=0.23, F(4,88)=0.93, p<.05)*. When running this MANCOVA, normality is assured and the variance among groups appears to be equal for both attitude *(F(5,50)=1.38, p=.25)* and behavioural intention towards policy instruments *(F(5,50)=1.27, p=.29)*. However, the assumption about equality of covariance matrices is violated: *F(15,3631)=2.65, p<0.01*. The literature is not clear about what the implications of this violation are and which of the test statistics of MANCOVA is the most robust against this violation. As a result, this study will compare and take into account all four test statistics, i.e., Pillai's trace, Hotelling's trace, Wilks' lambda and Roy's largest root. Taking this complication into account, the result of this MANCOVA proves on all four test statistics that the covariate ACOMP has a non-significant effect on the statistical model *(all four ps=.15)*. Because of this, and since this covariate accounts for one degree of freedom, the covariate is omitted from the statistical model. As a result, the attitude and behavioural intentions toward policy instruments among stakeholder groups and experimental conditions for the post-test data are analysed through a MANOVA instead of an MANCOVA.

Last, Kruskal-Wallis tests are performed for the post-test data on (1) the attitude towards the used computer simulation model, (2) the perceived internal validity of the simulation model, (3) learning about the effect policy instruments have on the fisheries system, and (4) learning about how difficult it is to manage a fisheries system in an attempt to determine significant differences among stakeholder groups. Mann-Whitney U tests are the *post hoc* tests, all Bonferroni adjusted (α'=0.02 since k=3 where k equals the number of stakeholder groups). Non-parametric tests are chosen because (1) tests for normality are often heavily violated, (2) data transformations do not work, and (3) sample sizes are small.

The last step is to investigate the differences between pre- and post-test among stakeholder groups in a quest to determine changes in (1) subjective knowledge, (2) attitude and (3) behavioural intention towards policy instruments due to the experimental condition. The difference in subjective knowledge is originally analysed through a mixed design ANCOVA with both ACOMP and ACSM as covariates. A mixed design ANCOVA can be performed since (1) normality can only be slightly doubted for the pre-test data of the group of policymakers in the experimental group since *D(13)=0.20, p=.15* but *W(13)=0.83, p<.05*, and (2) homogeneity of variance is assumed for both pre- and post-test data: *F(5,50)=0.30, p=.91 and F(5,50)=1.23, p=.31,* respectively. Additionally, ACOMP and ACSM can be used as covariates since the assumptions of (1) independence of the covariate and treatment and (2) homogeneity of regression slopes are both met. However, the results of this mixed design ANCOVA illustrate a non-significant effect for each of the two covariates on both "within-subject variables" and "between-subject variables". Since each covariate absorbs one degree of freedom, this study omits the covariates from the analysis resulting in a mixed design ANOVA with (1) "the state" of subjective knowledge in pre- and post-test as "within-subject variables" and (2) stakeholder group and experimental condition as "between-subject variables". The analysis of both attitude and behavioural intention towards commonly used policy instruments follow the same approach. They also both start off with a mixed design ANCOVA and discover that or (1) the assumption of homogeneity of regression slopes is not met, or (2) the covariates do not have a significant effect on the statistical model. As a result, differences between pre-and post-test data for attitude and behavioural intention towards commonly used policy instruments are also analysed through mixed design ANOVAs.

5.3 Results

5.3.1 Pilot testing the questionnaire for its reliability

The paired sample t-tests and Wilcoxon signed-rank test statistically prove that the developed questionnaire is reliable since (1) subjective knowledge, (2) attitude towards policy instruments, (3) behavioural intention towards policy instruments, (4) attitude towards computers, and (5) attitude towards computer simulation models do all not significantly differ between test and retest (Table 5.5). In addition, the Cronbach's Alphas for each of these constructs and for both test and retest data all range between "very satisfying" to "excellent" (Table 5.5).

Table 5.5: Test-retest reliability and Cronbach's Alphas for the pilot test data

	Test-retest reliability					Cronbach's Alpha	
	Descriptive statistics		Test statistic	Sig.	r	Test (n=15)	Re-test (n=15)
	Test (n=15)	Re-test (n=15)					
Subjective knowledge[a]	4.28 (1.40)	4.19 (1.05)	t=0.378	.711	.10	.90	.67
Attitude towards policy instruments[b]	4.64	4.50	z=0.201	.201	-.23	.86	.93
Behavioural intention toward policy instruments[a]	4.27 (0.82)	4.50 (0.74)	t=-2.132	.051	.50	.81	.84
Attitude toward computers[a]	5.36 (0.87)	5.20 (1.03)	t=0.763	.458	.20	.78	.87
Attitude toward computer simulation models[a]	4.83 (0.84)	4.71 (0.90)	t=0.786	.445	.21	.84	.77

[a]: Paired sample t-test, descriptive statistics: Mean (St dev)
[b]: Wilcoxon signed-rank test, descriptive statistic: Median

(Source: Own data)

5.3.2 Results of the pre-test data

Table 5.6 reveals some slight differences in demographic characteristics. The ship owners and skippers in the experimental group are older compared to those in the control group and that the opposite is true for the policymakers. As a result, these two differences between experimental and control group should be taken into account when interpreting the results that follow.

Table 5.6: Demographic characteristics of the experimental and control group by stakeholder group (#subjects (%))

		Experimental group (n=29)			Control group (n= 28)		
		Fishermen (n=6)	Scientists (n=10)	Policymakers (n=13)	Fishermen (n=6)	Scientists (n=10)	Policymakers (n=12)
Gender	Male	6 (100%)	7 (70%)	12 (92.3%)	6 (100%)	6 (60%)	9 (75%)
	Female	0 (0%)	3 (30%)	1 (7.7%)	0 (0%)	4 (40%)	3 (25%)
Age	<36	0 (0%)	7 (70%)	2 (15.4%)	0 (0%)	7 (70%)	7 (58.3)
	36-45	1 (16.7%)	2 (20%)	2 (15.4%)	4 (66.7%)	1 (10%)	1 (8.3%)
	>46	5 (83.3)	1 (10%)	9 (69.2%)	2 (33.3)	2 (20%)	4 (33.3%)

(Source: Own data)

Table 5.7 shows the correlations between each of the five constructs of the pre-test. There are only two highly significant and relatively strong correlations (indicated in **bold**). First, attitude is significantly and positively related to behavioural intention towards policy instruments, *r=.55, p(two-tailed)<.01*. Second, attitude towards computers is significantly and positively related to attitude towards computer simulation models, *r=.44, p(two-tailed)<.01*. Following the theoretical evaluation frameworks of both Huz *et al.* (1997) and Gröβler (2001), these correlations were expected and result in (1) a factorial ANOVA on subjective knowledge, (2) a MANOVA on both attitude and behavioural intention towards policy instruments, and (2) a MANOVA on both attitude towards computer and computer simulation models.

Table 5.7: Correlations between each of the five constructs of the pre-test (n=57) (superscript "a" = "Pearson's r" and "b" = "Kendall's tau")

	SK[a]	APOINS[a]	BIPOINS[a]	ACOMP[b]	ACSM[a]
SK	1.00	-.15	-.19	.17	.16
APOINS		1.00	**.55****	-.14	.00
BIPOINS			1.00	-.29*	-.29*
ACOMP				1.00	**.44****
ACSM					1.00

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
(Source: Own data)

Table 5.8 summarises the descriptive statistics for the pre-test data. The factorial ANOVA on subjective knowledge unveils only a significant main effect of stakeholder group on subjective knowledge, $F(2,51)=4.32, p<.05, \text{partial } \eta^2=.15$. Subsequent Hochberg's GT2 *post hoc* tests indicate that subjective knowledge is significantly lower for scientists (average of 3.99) compared to policymakers (average of 5.15), both *ps<.05*. Subjective knowledge is not significantly different between the other stakeholder groups. The other main effect of experimental condition on subjective knowledge was non-significant ($F(1,51)=0.01, p=.93, \text{partial } \eta^2=0$) as well as the interaction effect between stakeholder group and experimental condition ($F(2,52)=0.73, p=.49, \text{partial } \eta^2=.03$).

Using Pillai's trace, the MANOVA on attitude and behavioural intention towards policy instruments only reveals a significant effect of stakeholder group on attitude and behavioural intention towards policy instruments, *V=0.24, F(4,102)=3.39, p<.05*. The experimental condition *(V=0.01, F(2,50)=0.14, p=.87)* and the interaction effect between stakeholder group and experimental condition *(V=0.06, F(4,102)=0.75, p=.57)* are both non-significant. Subsequently, separate univariate ANOVAs on both dependent variables with stakeholder group as the independent variable reveal only a significant effect on attitude towards policy instruments among the different stakeholder groups, *F(2,54)=4.20, p<.05,* η^2*=.14*. As a result, behavioural intention towards policy instruments between stakeholder groups does not differ significantly, *F(2,54)=0.24, p=.79,* η^2*=.01*. Finally, the Hochberg's GT2 *post hoc* tests reveal that policymakers have a significantly better attitude towards commonly used policy instruments on average (i.e., 4.46) than ship owners and skippers (i.e., 3.90).

Finally, the MANOVA that analyses attitude towards computer and computer simulation models conjointly finds neither a significant effect of stakeholder group, nor of experimental condition on both attitude and behavioural intention towards computers and computer simulation models. Using Pillai's trace, the test statistics are respectively *V=0.10, F(4,102)=1.36, p=.25* and *V=0.05, F(2,50)=1.18, p=.32*. The interaction effect between stakeholder group and experimental condition is also non-significant*, V=0.10, F(4,102)=1.34, p=.26*.

Table 5.8: Descriptive statistics of the pre-test data (Mean (St Dev))

	Experimental group (n=29)			Control group (n= 28)		
	Fishermen (n=6)	Scientists (n=10)	Policymakers (n=13)	Fishermen (n=6)	Scientists (n=10)	Policymakers (n=12)
Subjective knowledge	4.63 (1.36)	3.80 (1.13)	5.42 (1.26)	4.70 (1.37)	4.18 (1.49)	4.87 (1.28)
Attitude towards policy instruments	3.84 (0.94)	4.38 (0.45)	4.46 (0.46)	3.97 (0.57)	4.42 (0.73)	4.46 (0.43)
Behavioural intention	4.35 (1.20)	4.18 (0.63)	4.09 (.067)	4.29 (0.57)	4.15 (0.84)	4.51 (0.44)
Attitude towards computers	5.21 (1.32)	5.30 (0.69)	5.74 (0.50)	4.75 (0.89)	5.46 (0.60)	5.48 (0.80)
Attitude towards computer simulation models	4.90 (1.09)	4.66 (0.73)	5.35 (0.54)	4.97 (0.87)	5.36 (0.65)	5.04 (0.83)

(Source: Own data)

5.3.3 Results of the post test

Table 5.9 contains the correlations between each of the seven constructs of the post-test. There are five highly significant and rather strong correlations (indicated in **bold**). First, attitude towards policy instruments is significantly and positively related to behaviour intention towards policy instruments, *r=.65, p(two-tailed)<.01*. This correlation is in line with the correlation found in the pre-test and therefore confirms the choice of MANOVA. Second, the attitude towards the used simulation models is significantly and positively related to its perceived validity, *r=.60, p(two-tailed)<.01*. Third, both attitude towards the simulation model used and its perceived validity are significantly and positively related to learning from the use of the microworld about the effect policy instruments have on the fisheries system: *r=.48, p(two-tailed)<.01* and *r=.52, p(two-tailed)<.01*, respectively. Finally, learning from the microworld about the effect policy instruments have on the fisheries system is significantly and positively correlated to learning from the microworld about how difficult it is to manage a fisheries system, *r=.61, p(two-tailed)<.01*.

Table 5.9: Correlations between each of the five construct under research for the post-test data (superscript "a" = "Pearson's r" and "b"= „Kendall's tau")

	SK[a]	APOINS[a]	BIPOINS[a]	AMODEL[a]	VALMODEL[a]	LEARNEFF[b]	LEARNMAN[b]
SK	1.00	-.14	-.11	.03	.23	-.06	-.20
APOINS		1.00	**.65****	.46*	.25	.26	.20
BIPOINS			1.00	.12	.09	-.02	-.06
AMODEL				1.00	**.60****	**.48****	.29*
VALMODEL					1.00	**.52****	.31*
LEARNEFF						1.00	**.61****
LEARNMAN							1.00

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
(Source: Own data)

Table 5.10 summarises the descriptive statistics for the post-test data. The factorial ANOVA on subjective knowledge unveils only a significant main effect of stakeholder group on subjective knowledge, *F(2,51)=6.58, p<0.01, partial* η^2*=.21*. Subsequent Hochberg's GT2 *post hoc* tests indicate that subjective knowledge is significantly lower for scientists (average 3.63) compared to both policymakers (average 4.81) *(p<.01)* and ship owners and skippers (average 4.93) *(p<.05)*. The subjective knowledge is not significantly different between policymakers and ship owners and skippers *(p=.99)*. The other main effect of experimental condition *(F(1,51)=0.83, p=.37, partial* η^2*=.02)* and the interaction between stakeholder group and experimental condition *(F(2,51)=0.70, p=.50, partial* η^2*=.03)* are both non-significant.

The results of the MANOVA on the attitude and behavioural intentions toward policy instruments among stakeholder groups and experimental conditions are all non-significant based on all four test statistics (i.e., Pillai's trace, Hotelling's trace, Wilks' lambda and Roy's largest root). To illustrate this yet remain concise, this study only gives the Pillai's trace statistics: (1) *V=0.11, F(4,100)=1.44, p=.23* for stakeholder group, (2) *V=0.03, F(2,49)=0.79, p=.46* for experimental condition, and (3) *V=0.07, F(4,100)=0.87, p=.49* for the interaction effect. However, taking into account the violation of the assumption on equality of covariance matrices *(F(15,3631)=2.65, p<0.01)*, one should interpret these findings with caution. Nevertheless, even if statistical differences were overlooked, these differences would only be marginally relevant because all group means are closely situated around 4.5 for both attitude and behavioural intentions toward policy instruments.

The results of the Kruskal-Wallis tests for (1) attitude towards the computer simulation model *(H(2)=0.91, p=.63, η²=.03)*, (2) perceived internal validity of the simulation model *(H(2)=4.53, p=.10, η²=.16)*, (3) learning about the effect policy instruments have on the fisheries system *(H(2)=1.43, p=.49, η²=.05)*, and (4) learning about how difficult it is to manage a fisheries system *(H(2)=3.26, p=.20, η²=.12)* were all non-significant. As a result, all stakeholder groups have the same positive attitude towards the used computer simulation model (overall median: 5.25) and all stakeholder groups perceive the internal validity of the simulation model as medium-high (overall median: 4.56). Finally, they also reported that they all have learned the same high amount (1) about the effect policy instruments have on the fisheries system (overall median: 7.00), and (2) about how difficult it is to manage a fisheries system (overall median: 7.00).

Table 5.10: Descriptive statistics of the post-test data (Mean (St Dev) or Median)

	Experimental group (n=29)			Control group (n= 28)		
	Fishermen (n=6)	Scientists (n=10)	Policymakers (n=13)	Fishermen (n=6)	Scientists (n=10)	Policymakers (n=12)
Subjective knowledge	5.33 (0.73)	3.52 (1.10)	4.97 (1.00)	4.53 (1.32)	3.74 (1.49)	4.63 (1.36)
Attitude towards policy instruments	4.14 (1.00)	4.47 (0.61)	4.53 (0.54)	4.23 (0.74)	4.52 (0.80)	4.46 (0.58)
Behavioural intention	4.74 (1.13)	4.50 (0.67)	4.35 (0.64)	4.25 (0.52)	4.50 (0.97)	4.38 (0.44)
Attitude towards the used model	5.44	4.94	5.50			
Perceived internal validity of the model	4.94	4.91	4.38			
Learning about effects policy instruments have on the fisheries system	6.50	7.00	7.00			
Learning about how difficult it is to manage fisheries systems	7.00	8.00	7.00			

(Source: Own data)

5.3.4 Differences between pre-and post-test

The mixed design ANOVA on subjective knowledge unveils no significant differences between pre-and post-test data *(F(1,51)=1.45, p=.23, partial η²=.03)* even when taking into account the interaction with (1) stakeholder group *(F(2,51)=2.41, p=.10, partial η²=.09)*, (2) experimental condition *(F(1,51)=1.28, p=.26, partial η²=.03)*, and (3) both of them *(F(2,51)=1.59, p=.22, partial η²=.06)*. Next, the main effect of experimental condition was also non-significant *(F(1,51)=0.27, p=.61, partial η²=.01)*, but the main effect of stakeholder group was highly significant *(F(2,51)=5.75, p<.01, partial η²=.18)*. Subsequent Hochberg's GT2 *post hoc* tests indicate that the subjective knowledge of scientist (average of 3.81) was significantly lower compared to policymakers (average of 4.98) *(p<.01)* but not compared to ship owners and skippers (average of 4.80) *(p<.10)*. Policymakers and ship owners and skippers did not significantly differ *(p=.96)*. Finally, the interaction between stakeholder group and experimental condition was non-significant, $F(2,51)=0.60, p=.55$, partial $\eta^2=.02$.

The mixed design ANOVA on attitude towards policy instruments unveils a significant difference between pre-and post-test data, $F(1,51)=5.93, p<.05$, partial $\eta^2=.10$. As a result, attitude towards policy instruments was slightly lower in the pre-test (average 4.32) compared to the post-test (average 4.43). The interaction of this effect with (1) stakeholder group ($F(2,51)=1.52, p=.23$, partial $\eta^2=.06$), (2) experimental condition ($F(1,51)=0.09, p=.77$, partial $\eta^2=0$), and (3) both stakeholder group and experimental condition ($F(2,51)=0.05, p=.95$, partial $\eta^2=0$) were all non-significant. The main effects of stakeholder group and experimental condition were both non-significant, respectively $F(2,51)=2.30, p=.11$, partial $\eta^2=.09$ and $F(1,51)=0.06, p<.81$, partial $\eta^2=0$. Lastly, the interaction between stakeholder group and experimental condition was also non-significant, $F(2,51)=0.06, p=.94$, partial $\eta^2=0$.

Finally, the mixed design ANOVA on behavioural intention towards policy instruments unveils a significant difference between pre-and post-test data, $F(1,50)=5.66, p<.05$, partial $\eta^2=.10$. As a result, attitude towards policy instruments was lower in the pre-test (average 4.25) compared to the post-test (average 4.44). The interaction of this effect with (1) stakeholder group ($F(2,50)=2.13, p=.13$, partial $\eta^2=.08$), (2) experimental condition ($F(1,50)=2.02, p=.16$, partial $\eta^2=.04$), and (3) both stakeholder group and experimental condition ($F(2,51)=1.12, p=.33$, partial $\eta^2=.04$) were all non-significant. Next, the main effects of stakeholder group and experimental condition were both non-significant, respectively $F(2,50)=0.16, p=.86$, partial $\eta^2=.01$ and $F(1,50)=0.10, p<.76$, partial $\eta^2=0$. Finally, the interaction between stakeholder group and experimental condition was also non-significant, $F(2,50)=0.79, p=.46$, partial $\eta^2=.03$.

5.4 Discussion

For many years, there has been a dearth of well-structured evaluation research that tackles the research question whether any valuable "learning" takes place from the use of microworlds (Akili, 2007; Bakken *et al.*, 1994; Bell *et al.*, 2008; Cavaleri *et al.*, 1997; Gosen *et al.*, 2004; Gresse von Wangenheim *et al.*, 2009; Huz *et al.*, 1997; Raia, 1966; Sweeney *et al.*, 2000; Tonks *et al.*, 1997; Wolfe, 1976). This study starts to remedy this lack by investigating if actual decision makers learn from using microworlds. We use the Belgian fisheries system as a case study using an existing microworld that allows stakeholders to learn about the effects policy instruments have on the Belgian fisheries system. Learning is measured through learning criteria drawn from the evaluation frameworks of Huz *et al.* (1997) and Gröβler (2001) and applied to the case of Belgian fisheries. This study tests the influence a microworld has on stakeholder's (policymakers, scientists and ship owners and skippers) subjective knowledge, attitude and behavioural intention about commonly used policy instruments in Belgium using a "before-after with control group"-experimental design. In addition, this study also compares the attitude of stakeholders towards the microworld used as well as their perceived internal validity of the microworld. Finally, the study compares if stakeholders have reported differences in learning from the microworld about (1) the impact policy instruments have on fisheries systems, and about (2) how difficult it is to manage fishery systems.

The results of the analysis on the pre-test data addressed the first two hypotheses listed in Table 5.11. Only small differences were found in the age structure of participants between experimental and control group. More importantly, however, there were no significant differences discovered between those two groups on (1) subjective knowledge, attitude and behavioural intention towards policy instruments; and (2) attitude towards computers and computer simulation models. As a result, the first hypothesis is accepted. This implies that the two randomly selected treatment groups were initially equal. Further analysis on the pre-test data discovered that subjective knowledge was significantly higher for policymakers compared to scientists. In addition, they had also a significantly better attitude towards policy instruments compared to ship owners and skippers. Consequently, the second hypothesis is rejected. Next, the results of the analysis on the post-test data addressed the third and fourth hypothesis. These results accept the third hypothesis: the two treatment groups did not differ significantly on subjective knowledge, attitude and behavioural intention towards policy instruments after being exposed to the experimental treatments. The fourth hypothesis is rejected since subjective knowledge was after the experiment significantly lower for scientists compared to both (1) policymakers and (2) ship owners and skippers. Finally, results of the analyses on the differences between pre- and post-test addressed the last three hypotheses. These results reveal no significant differences between pre-and post-test for subjective knowledge. However, both attitude and behavioural intention toward policy instruments were slightly lower in the pre-test compared to the post-test. Consequently, hypothesis five is rejected. Both treatments (even the treatment in the control group which was not relevant) caused changes in stakeholder's attitude and behavioural intention. This could be due to the Hawthorn effect, although this seems highly unlikely since the experiment was "disguised" (Christensen, 1997: 294) and informal contact with the participants after the experiment confirmed that they had no idea that they were participating in an experiment. Next, this study found no differences due to the experimental condition between subjective knowledge, attitude and behavioural intention towards policy instruments when taking pre-and post-test into account. As a result, differences in attitude and behavioural intention could not be attributed to the use of the microworld. Therefore, the sixth hypothesis is accepted. Finally, when taking pre-and post-test into account, the seventh hypothesis is rejected since the subjective knowledge of scientists was significantly lower compared to policymakers. Policymakers and ship owners and skippers did not significantly differ.

Table 5.11: Summary of the outcomes for the hypotheses

Hypothesis		Accepted or rejected
$H0_1$:	There will be no differences in pre-test scores between the two treatment groups (i.e., the two randomly selected treatment groups will be equal).	Accepted
$H0_2$:	There will be no differences in pre-test scores between the different stakeholder groups (i.e., all stakeholder groups are initially the same related to the dependent variables).	Rejected
$H0_3$:	For the dependent variables that were measured in both experimental treatments, there will be no differences in the post-test scores between the two treatment groups (i.e., the two groups will (still) be equal after having played with the microworld).	Accepted
$H0_4$:	There will be no differences in post-test scores between the different stakeholder groups (i.e., all stakeholder groups are (still) the same related to the dependent variables after having played with the microworld).	Rejected
$H0_5$:	There will be no differences between pre- and post-test scores for the dependent variables that were measured in these two tests (i.e., both treatments caused no changes in subjective knowledge, attitude, and behavioural intention).	Rejected
$H0_6$:	The differences between the pre- and post-test scores on the dependent variables that were measured in both tests are the same for both treatment groups (i.e., the microworld caused no changes in subjective knowledge, attitude, and behavioural intention).	Accepted
$H0_7$:	The differences between the pre- and post-test scores for the dependent variables that were measured in both tests are the same for all stakeholder groups (i.e., stakeholder groups report the same changes in subjective knowledge, attitude, and behavioural intention independent from the treatment condition).	Rejected

(Source: Own compilation)

This research indicates that using the microworld did not result in changes in participants' subjective knowledge, attitude and behavioural intention towards commonly used policy instruments in Belgian fisheries management. This outcome contradicts all stakeholders' reports that they had learned from the microworld about the effect policy instruments have on the fisheries system and that they had confidence in the microworld and perceived the microworld to be valid. As such, alternative explanations for these results need to be considered. Three alternative explanations for this outcome are worth discussing: (1) methodological issues made it impossible to detect changes in participant's subjective knowledge, attitude and behavioural intention, or (2) the way in which the microworld was administered did not result in changes in participant's subjective knowledge, attitude and behavioural intention, or (3) participants have not "learned" anything new from the microworld and therefore no changes in participant's subjective knowledge, attitude and behavioural intention occurred. Let's discuss each of these possible explanations in more details in an attempt to determine which of these is most plausible.

Although this study has paid extensive attention to methodology compared to most other similar studies, there still remain methodological limitations that could have jeopardised the detection of any actual change in subjective knowledge, attitude and behavioural intention. The first and perhaps most important limitation is the questionable testing of the validity of the questionnaires. Although the measurement scales in these questionnaires were derived or even literally borrowed from the peer reviewed literature and tested for their reliability, it is possible that these scales were not sensitive enough to discover subtle changes in subjective knowledge, attitude and behavioural intention. In addition, applying structural equations modelling next to the test-retest reliability and the Cronbach's Alphas could have confirmed the validity of these questionnaires more thoroughly. However, the small sample size would have made this difficult, if not impossible. As such, future research on assessing learning from microworlds, at least the ones with sufficiently large sample sizes, should test all dimensions of the validity of their questionnaires through structural equations modelling. Second, and also next in order of importance, is that this study (subjectively) measured learning from microworlds through a questionnaire which may not have measured the real learning effect (Ely *et al.*, 2007; Gentry *et al.*, 1998; Gresse von Wangenheim *et al.*, 2009; Pfahl *et al.*, 2004) (i.e., questionable construct validity) . A third methodological limitation of this study could have been its small sample size. Cowles (1974) suggests that if an analyses of variance design with several levels of the dependent variable is being used, then fifteen participants per group (i.e., cell in crosstab) is recommended. Many previous studies have also encountered the problem of small sample sizes (e.g.: Cavaleri *et al.*, 1997; Drappa *et al.*, 2000; Gresse von Wangenheim *et al.*, 2009; Hung, 2008; Huz *et al.*, 1997; Pfahl *et al.*, 2001; Pfahl *et al.*, 2004; Sindre *et al.*, 2009). But the Belgian fishing industry is small and larger sample sizes are difficult to obtain. In addition, performing rigidly controlled experiments on large samples, especially when using computers, is not only expensive but also difficult (hard to guarantee strict control), if not impossible. Nevertheless, in an attempt to collect more data, the authors of this study have a request pending to replicate this study within the European Commission. A fourth, fifth and sixth limitation lie within the nature of the "before-after with control group"-design. Although such a design has a lot of strengths compared to other true experimental designs, it has a major disadvantage: the "pre-test effect" (Christensen, 1997: 486). As a result, participants could have remembered what they have answered in the pre-test and stuck to these pre-test answers in the post-test rather than reconsider their answers based on the learning activity in between. Similar studies (e.g.: Sindre *et al.*, 2009) have also considered this as a possible explanation for not detecting a learning effect in their studies. However, this study has tried to limit the "pre-test effect" by clearly indicating in the post-test questionnaire, and even in its individual measurement scales, that is was legitimate to change answers compared to the pre-test. Besides this pre-test effect, a "before-after with control group"-design can also not control for "intra-group difference" (Christensen, 1997). However, the latter has been limited through isolating the participants from each other during the experiment as much as possible. Nevertheless, in the experimental group of the scientists, a dominant figure repeatedly distorted the scientific integrity of the experiment through making his personal opinions known. However, the results of this group were not significantly different from the observations in the other sessions. Hence, it remains unclear to what extent these personal opinions hypothecated the results of this study. A last limitation of the "before-after with control group"-design is that it cannot completely control for "confounding user characteristics" (Größler, 2001: 14) (e. g., participant's motivation, their expertise in working with computers, their general intelligence etc.) either. However, this study has partly dealt with these confounding user characteristics by (1) a successful random assignment of participants to the experimental and control group, and (2) including two of these potentially confounding user characteristics as covariates (i.e., attitude towards (1) computers and (2) computer simulation models) in our analyses. Nevertheless, complete control over these confounding user characteristics is impossible and is a problem for all evaluation studies based on experiments (Größler, 2004). An seventh limitation could have been that the small differences which were found in the age structure of the participants between experimental and control group may have jeopardised the results of this study. However, this is highly unlikely since there were no significant differences discovered between those two groups on (1) subjective knowledge, attitude and behavioural intention towards policy instruments; and (2) attitude towards computers and computer simulation models before the actual experiment started. An eighth limitation could have been that participants were insufficiently motivated by the monetary incentives, in this case the iPods. Consequently, participants may have not put much effort into the tasks related to the experiment (Sweeney *et al.*, 2000). Perhaps this study should have used real monetary incentives proportionally to each participant's performance in the experiment (Smith, 1982). However, studies have encountered conflicting evidence about the value monetary incentives have when investigating learning from microworlds (Camerer *et al.*, 1999; Sweeney *et al.*, 2000). In fact, monetary incentive could also have blocked learning through the phenomenon of "competitive gaming". This refers to the process in which learning becomes subordinate to winning due to competition. People want to be the winner of the competition and as such, learning becomes only a by-product (De Geus, 1997). Hence, it is not clear what the effect of our monetary incentives were on learning from our microworld. Nevertheless, we included them since there is still stronger evidence in favour of including such incentives in the experimental design instead of not including them (e.g.: Camerer *et al.*, 1999). Last but far from least is the limited amount of time participants were able to play with the microworld (Sweeney *et al.*, 2000). Perhaps a one hour introduction to the microworld was insufficient to result in changes in subjective knowledge, attitude and behavioural intention. This discussion brings us to the second potential explanation of the failure in detecting differences between subjective knowledge, attitude and behavioural intention: perhaps the way in which we have administered the microworld to the participants could not have had resulted in changes in participant's subjective knowledge, attitude and behavioural intention.

This potential explanation is highly interesting. The administration of the microworlds needs to be "realistic", meaning that one should administer the microworld to the participants as if it were not for an experiment. In addition, the duration of letting the participants play with the microworlds also contains a "dangerous" hidden trade-off in an experimental design. On the one hand, participants need to be exposed long enough to the microworld to allow them to play and learn from it. As a result, the probability that learning occurs from the microworld is increased when extending the time participants can play with the microworld. However, on the other hand, prolonging the time participants can play with the microworlds also prolongs the duration of the whole experiment. This results in an increased probability of inaccurately measuring learning, since higher error rates may occur when filling out the post-test due, for instance, to the increased fatigue of the participants (Christensen, 1997; Gresse von Wangenheim *et al.*, 2009; Größler, 2004). Although one can counter with the argument that such problems are controlled through using a control group, they can still make it impossible to detect a potential learning effect since an increased error rate mostly results in increased variation in the data which makes it often impossible to statistically discover actual existing differences between treatment groups (i.e., type II error in statistics (Field, 2009)). Therefore, as a result of this trade-off, this study chooses to administer the microworld to the participants for about one hour (i.e. similar to Gresse von Wangenheim *et al.*, 2009 and; Sindre *et al.*, 2009 who administered the model for respectively 100 and 90 min). One hour was seen as a good compromise. Additionally, it was also seen as a realistic proxy of the time stakeholders would have played with the microworld in a non-experimental setting. Nevertheless, it remains highly possible that the participants did not have enough time to play. Similar studies (e.g.: Gresse von Wangenheim *et al.*, 2009; Sweeney *et al.*, 2000) also questioned the short duration of the administration of their microworld to the participants when learning effects were not detected. Additionally, some of these studies (e.g.: Cavaleri *et al.*, 1997; Gresse von Wangenheim *et al.*, 2009; Warren *et al.*, 1999) also question whether playing the microworld once is sufficient to result in significant learning effects since it is difficult to change the deeply held mental models (i.e., a person's "deeply held internal images of how the world works" (Senge, 1990: 174), which also contains the attitudes and beliefs (Cavaleri *et al.*, 1997)) that drive behaviour. Hence, it may be possible that participants will only benefit from repeated exposure to different sessions.

Other ways in which the microworld could have been administered should also be discussed. In fact, similar studies in which the participants (although often students) could only play with the microworld came to similar conclusions of participants not learning from the microworld. In a recent study, Gresse von Wangenheim *et al.* (2009: 443) concluded that "although most participants subjectively believe that playing the game helped them to learn, results from the statistical tests do not support these subjective evaluations". Similarly, Pfahl *et al.* (2001: 284) concluded that "just running a simulation model as a black box may not be sufficient to have people gain insights into the software development process, and accept to alter their mental model" whereas Drappa *et al.* (2000: 207) concluded that "just playing is not enough, because the students are not able to understand the reasons why they have failed". A number of other studies have also failed to find learning effects from simulation models (e.g.: Cameron *et al.*, 2005; Ellis *et al.*, 2005; Thomas *et al.*, 1991). As a result, scientific communities are currently still discussing how microworlds should be used or designed in an attempt to allow decision makers to learn from them. Many options are possible, which leads to unstructured research (Wolfe, 1976). For instance, one group of studies (e.g.: Langley, 1995; Langley *et al.*, 2004; Sengupta *et al.*, 1993a; Sengupta *et al.*, 1993b) focuses on extending the microworld with cognitive feedback and feedforward as a valuable attempt to make learning possible from microworlds. The user-friendly interface, for instance, should make key linkages between policy choices and outcomes explicit. It should illustrate how causal mechanisms operate in the simulation model. Others (e.g.: Langley *et al.*, 1996; McCormack *et al.*, 1998) have investigated the importance of running the microworlds in the policy development mode ("continuous simulation", sometimes called "simulation") versus the dynamic decision-making mode ("stepwise simulation", sometimes called "gaming") but could not prove that one is superior to the other. Again others (e.g.: Terek *et al.*, 1999) have investigated the impact of different predefined performance goals in playing the microworld on learning from microworlds. These studies found that the way these predefine goals are set resulted in different learning effects. A final group of studies, and perhaps the most promising one of them all, claim that "learning" and therefore the main benefit of microworld lies within the model building and thus not within the application of an existing microworld (Lane, 1995; Pfahl *et al.*, 2004). As such they believe that if decision makers have to learn from a microworld, then they need to be actively involved from the beginning of the modelling process (Pfahl *et al.*, 2004). As such, they are the advocates of group model building (e.g.: Rouwette *et al.*, 2002; Vennix, 1990; Vennix, 1996). However, the downside to group model building is that it requires a vast amount of different resources (skills, time, money, etc.). Hence, most modelling exercises still do not follow the principles of group model building (see Andersen et al. (1997)). Consequently, future research on learning from microworlds should not focus too heavily on learning from microworlds in group model building processes.

The final alternative explanation of why this study was unable to detect changes in subjective knowledge, attitude and behavioural intention is that participants may have not "learned" anything new from the microworld and therefore did not change their subjective knowledge, attitude and behavioural intention compared to the pre-test (Sindre *et al.*, 2009). It could be that the microworld only confirmed what they already knew about the impact policy instruments have on the fisheries system and therefore did not change their subjective knowledge, attitude and behavioural intention towards these policy instruments. As such, the microworld was perhaps too simple or the participants already had an accurate idea of the effect policy instruments have on the Belgian fisheries system. However, studies (e.g.: Raia, 1966) have clearly indicated that simple microworlds provided essentially the same learning benefits as relatively more complex ones. Hence, learning is most likely not directly proportional to the degree of complexity of the microworld. Alternatively, it is also possible that participants only enriched their ideas rather than revising them, which led to no change in their subjective knowledge, attitude and behavioural intention towards these policy instruments (Pala *et al.*, 2005; Vosniadou, 1994). Another possibility is that the participants' "bounded rationality" (Simon, 1976) could have blocked actual learning from the microworld (Sweeney *et al.*, 2000: 251). Finally, it may also be the case that learning will only take place later when the participants reflect on the microworld in response to exposure to information regarding fisheries management strategies in the real world.

However, all of these alternative explanations miss the most obvious interpretation of them all: perhaps the participants simply didn't learn anything from the microworld, despite having reported the opposite. Perhaps the microworld was too difficult, too dynamically complex (or too boring) for learning to occur (Pfahl *et al.*, 2004). In such cases, "trail-and-error gaming" (Größler, 2004) can become more attractive even if monetary incentives are used to limit such behaviour. Other studies have come to the conclusion that participants frequently applied only relatively simple and unsophisticated problem-solving and decision-making techniques and that more attention was devoted to reacting to events than planning for them (Wolfe, 1975b). Research also suggests that individuals often do not make effective use of the "control" provided by simulation- or, even more broadly, technology-based trainings (Bell *et al.*, 2002;

DeRouin *et al.*, 2004; Reeves, 1993). Participants frequently do not accurately assess their current knowledge level or devote enough effort to training, and make poor decisions like skip over important learning opportunities (Brown, 2001; Ely *et al.*, 2007). Drappa *et al.* (2000) came to similar conclusions and even found that participants commit the same mistakes over and over again. Hence, participants did not reflect on the details of their game-performance and neither did they take the effort to analyse these results.

This brings us to discuss more fundamental questions like whether “experience is the best teacher” (Wolfe, 1975a: 450). Although this seems obvious in many cases, Wolfe *et al.* (1975a) reports that experiential learning is so unstructured that knowledge gained from experience may be fragmentary and haphazard. Additionally, they conclude that “there is no assurance that the student learns the „right’ thing” (Wolfe, 1975a: 450). As a result, it may be true that microworlds do not work on their own, meaning that there probably needs to be some structuring of the participants’ interactions with the microworld to obtain (or increase) learning effects (Bell *et al.*, 2008; Wolfe, 1975a). This greater learner control may be an important challenge facing simulation-based training designs since it seems important to identify effective guidance and support strategies for learning that can be embedded in the design of simulation-based training (Bell *et al.*, 2008; Cannon-Bowers *et al.*, 2009; Wolfe, 1975a). Reid *et al.* (2003), for instance, argue that learners need three types of support when handling microworlds. The first is “interpretive support”, which helps learners analyse the problem and activate relevant prior knowledge. The second is “experimental support” which helps learners engage in meaningful discovery learning activities. The final form of support is “reflective support”, which increases learners’ awareness of the discovery processes and helps them integrate those discovered rules and principles. Nevertheless, future research is needed to further determine the type of guidance that is most effective and how to embed guidance naturally into simulations so that it is not disruptive (Cannon-Bowers *et al.*, 2009). However, many researchers believe that guidance alone is not sufficient. They advocate that the true value of microworlds lies within its capability to rehearse and visualise strategies (Morecroft, 1999) so they can be brought into debate and discussion (Morecroft, 1984) among people. In our case, this could mean that microworlds could allow policymakers to better illustrate the implications of different policy strategies to other stakeholder groups, whereas these other stakeholder groups will see the difficulties encountered when managing fisheries more clearly. Hence, a better mutual understanding of the problems in fisheries policy could emerge from debate and discussion among the stakeholder groups of the fisheries system, resulting in changing attitudes toward policy systems. Consequently, high-order learning (i.e., changes in attitude and behaviour) may only occur through debating and discussing the results from the microworld within and between stakeholder groups. This idea is backed by Dill’s *et al.* (1963) finding that students remember what they have learn from the interactions with other people more vividly than what they have learn from playing with the microworld. Hence, it seems that a form of human interaction, and not only guidance, is required in learning from microworlds (Bell *et al.*, 2008). There are even researchers who go one step further and believe that a certain form of “classroom atmosphere” needs to be created for learning to take place in which the interactions among trainees and between trainees and trainers stands central. It is their belief that the kind of “learning community” offered by traditional, face-to-face instruction is essential for learning (Katz, 1999; Webster *et al.*, 1997). Nevertheless, advocates of the naturalistic decision-making movement argue the opposite. They claim that it is exactly this often unfamiliar and unrealistic “classroom atmosphere” which limits learning (Sweeney *et al.*, 2000). They believe people can perform well in familiar, naturalistic settings yet poorly on the same type of task in unfamiliar laboratory or training settings. Last, as already mentioned above, some researchers believe that the most effective way (and perhaps the only way) people learn from microworlds is when they are involved from the beginning of the modelling process in the form of group model building sessions.

In any case, the research presented here is a first step in contributing to evaluating learning from microworlds. This study cannot conclude that decision makers actually learn from microworlds. More work is needed to fully realise the potential of microworlds in learning processes, yet researchers are left with little guidance on how to develop an effective “learning system” as the factors that influence the effectiveness of simulation-based training remain unclear (Bell *et al.*, 2008; Warren *et al.*, 1999). Perhaps the most valuable guideline is to not only test “features” of microworlds on learning outcomes, but also to test which characteristics of the “users” and the “situation” (i.e., learning environment) determines these learning outcomes (Bell *et al.*, 2008; Größler, 2004). To be more effective, this kind of evaluation research should apply “before-after with control group”-designs in which the experimental group only differs from the control group by exactly one characteristic of the microworld, users or situation (Größler, 2001; Pfahl *et al.*, 2004). It should also adopt a “process-based approach” (Bell *et al.*, 2008) in which it aims to providing insights into the actual processes or mechanisms that explain learning effects from microworlds. Finally, future studies should also focus on replication, as studies have indicated the need for such replications because evaluation research often deals with low sample sizes (e.g.: Cavaleri *et al.*, 1997; Drappa *et al.*, 2000; Gresse von Wangenheim *et al.*, 2009; Hung, 2008; Huz *et al.*, 1997; Pfahl *et al.*, 2001; Pfahl *et al.*, 2004; Sindre *et al.*, 2009). Although such scientific research is often viewed as less valuable, the authors believe it is the only way to yield more generalised results in the future. We intend to replicate our experiment at the European Commission in an attempt to validate our findings and improve its external validity.

5.5 Conclusion

This study addressed the research question of whether any valuable “learning” takes place from the use of microworlds. Moreover, it took the opportunity to investigate if actual decision makers learn from using microworlds. For this, the Belgian fisheries was chosen as a case study and three stakeholder groups (policymakers, scientists and ship owners and skippers) were invited to participate in a “before-after with control group”-experiment which indicates that using the microworld did not result in changes in participant’s subjective knowledge, attitude and behavioural intention towards commonly used policy instruments in Belgian fisheries policy. This outcome contradicts the reports from all stakeholders groups where they state that they had learned from the microworld about the effect policy instruments have on the fisheries system and that they had confidence in the microworld and perceived its behaviour as valid. Alternative explanations for these results were discussed, being: (1) methodological issues made it impossible to detect changes in participant's subjective knowledge, attitude and behavioural intention, (2) the way in which the microworld was administered did not result in changes in participant's subjective knowledge, attitude and behavioural intention, or (3) participants have not learned anything new from the microworld and therefore no changes in participant's subjective knowledge, attitude and behavioural intention occurred.

However, all these alternative explanations ignore the most obvious one: participants perhaps did not learn anything from the microworld, even though participants reported the opposite. This calls the notion of "experience is the best teacher" (Wolfe, 1975a: 450) into question, since experiential learning is so unstructured that knowledge gained from experience may be fragmentary and haphazard. Hence, there probably needs to be some structuring of the participants' interactions with the microworld to obtain (or increase) learning effects (Bell *et al.*, 2008; Wolfe, 1975a). However, guidance alone is perhaps not sufficient since it seems that a form of human interaction in the form of debate and discussion (Morecroft, 1984) is required in learning from microworlds. There are even researchers who go one step further and believe that a certain form of "classroom atmosphere" or "learning community" is essential for learning (Katz, 1999; Webster *et al.*, 1997). Finally, most advocates of group model building (e.g.: Rouwette *et al.*, 2002; Vennix, 1990; Vennix, 1996) go still even further and state that group model building is the most effective, if not the only, way to learn from microworlds.

In any case, the research presented here is a first contribution to evaluating learning from microworlds. This study cannot conclude that decision makers learn from playing in microworlds. This suggests that more work is needed to fully realise the potential of microworlds in learning processes, yet researchers are left with little guidance on how to develop an effective "learning system" as the factors that influence the effectiveness of simulation-based training remain unclear (Bell *et al.*, 2008). Perhaps the most valuable guideline for future evaluation research is to start to apply "before-after with control group"-designs in which the experimental group only differs from the control group by exactly one characteristic of the microworld, users or environmental context (Größler, 2001; Pfahl *et al.*, 2004). It should also start adopting a "process-based approach" (Bell *et al.*, 2008) in which it aims to provide insights into the actual processes or mechanisms that explain learning effects from microworlds.

5.6 Acknowledgments

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5.7 Appendix

Appendix 1: Pre-test questionnaires of the experimental group

Questionnaire

Dear participant,

Thanks for taking the time to fill out this questionnaire. This questionnaire aims to determine your knowledge of commonly used policy instruments in Belgian fisheries, as well as your attitude toward them and your behaviour in relation to these instruments. Please answer these questions completely and truthfully. We guarantee that your answers will be treated **anonymously** and that only aggregated data will be included in reports and publications.

NOTE!: Many questions refer to the terms ‚fisheries system', ‚policy instruments' and ‚sub fleet'.

- *The term ‚fisheries system' includes (i) the Belgian fishing fleet and its overall performance, (ii) fish stocks, and (iii) governmental issues (both national and European) concerning fisheries.*
- *The term ‚policy instruments' refers to the group of instruments policy maker can use to manage the Belgian fisheries system. This group of instruments consists of (1) total quota, (2) the allocation of the total quota over Belgian's five sub fleets, (3) maximum fishing days per vessel, (4) maximum catch per fishing day, (5) licences, (6) decommissioning fees, (7) investment subsidies, and (8) fuel subsidies and taxes.*
- *The term ‚sub fleet' means a grouping of vessels with similar vessel characteristics, fishing method and target species.*

Your personal characteristics

Your gender:	Male ☐	Female ☐

Your age:	0-25 ☐	26-35 ☐	36-45 ☐	46-55 ☐	56-65 ☐	65+ ☐

Your work :	Owner or captain of a boat	☐
	ILVO	☐
	The Department of Agriculture and Fisheries of the Flemish Government	☐
	The Cabinet of the Flemish Government in charge of sea fisheries	☐
	DG Maritime Affairs and Fisheries of the EU	☐
	Cabinet of Commissioner Joe Borg	☐
	De Redercentrale	☐

Your knowledge about the effects policy instruments have on the fisheries system.
Please circle the number that best indicates how much you agree or disagree with each of the following propositions.

	Strongly disagree			**Neither agree nor disagree**			**Strongly agree**
I know pretty much about the effects policy instruments have on the fisheries system.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
I do not feel very knowledgeable about the effects policy instruments have on the fisheries system.	**1**	**2**	**3**	**4**	**5**	**6**	**7**

Among my close colleagues, I am one of the "experts" on assessing the effects of policy instruments on the fisheries system.	1	2	3	4	5	6	7
Compared to most other people, I know less about the effect policy instruments have on the fisheries system.	1	2	3	4	5	6	7
When it comes to the impact policy instruments have on the fisheries system, I really do not know a lot.	1	2	3	4	5	6	7

Your attitude towards policy instruments.
For each proposition, four pairs of adjectives are given. Please circle the number for each pair of adjectives that best reflects your opinion about the proposition.

Limiting total catches of a fleet through total quota is ……………………………………………...... for the fisheries system.

Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**

Dividing total quota over sub fleets is ……………………………………………………………....... for the fisheries system.

Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Useful**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**

Limiting the number of fishing days per vessel is ………………….……….……………………..…... for the fisheries system.

Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**

Limiting the catch per fishing day that a vessel can land is ……………………….……………….…. for the fisheries system.

Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**

Limiting the amount of vessels in a fleet through licences is ……………………………………….... for the fisheries system.

Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**

Decommissioning fees are ………………... for the fisheries system.

Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**

Investment subsidies are ……..…………………………………………………………………...... for the fisheries system.

Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**

Fuel subsidies are.......……………………………………………………………………….…..... for the fisheries system.

Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**

	Unfair	1	2	3	4	5	6	7	Fair

Fuel taxes are....………………………………………………………………...………... for the fisheries system.

Harmful	1	2	3	4	5	6	7	Beneficial
Good	1	2	3	4	5	6	7	Bad
Worthless	1	2	3	4	5	6	7	Valuable
Unfair	1	2	3	4	5	6	7	Fair

Your behavioural intentions towards policy instruments.

Please circle the number that best indicates how much you agree or disagree with each of the following propositions.

	Strongly disagree			Neither agree nor disagree			Strongly agree
If I find myself in a position to decide on fisheries management, I **intend** to ...							
... use total quota as a way to manage the fisheries system.	1	2	3	4	5	6	7
... divide the total quota over the sub fleets.	1	2	3	4	5	6	7
... limit the number of fishing days per vessel as a way to manage the fisheries system.	1	2	3	4	5	6	7
... limit the catch per fishing day that a vessel can land as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use licences as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use decommissioning fees as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use investment subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel taxes as a way to manage the fisheries system.	1	2	3	4	5	6	7

Your behavioural intentions towards policy instruments.

Please circle the number that best indicates how likely or unlikely your behaviour for each of the following propositions is.

	Very unlikely			Neither likely nor unlikely			Very likely
If you find yourself in a position to decide on fisheries management, how **likely or unlikely** is it that you would ...							
... use total quota as a way to manage the fisheries system.	1	2	3	4	5	6	7
... divide the total quota over the sub fleets.	1	2	3	4	5	6	7
... limit the number of fishing days per vessel as a way to manage the fisheries system.	1	2	3	4	5	6	7
... limit the catch per fishing day that a vessel can land as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use licences as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use decommissioning fees as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use investment subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7

... use fuel taxes as a way to manage the fisheries system.	**1**	**2**	**3**	**4**	**5**	**6**	**7**

Your attitude towards computers.
Please circle the number for each pair of adjectives that best reflects your opinion about computers. Think of computers in general terms.

Restrain creativity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Enhance creativity**
Helpful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Harmful**
Enjoyable to use	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Frustrating to use**
Boring	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Intriguing**
A sound investment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**A waste of money**
Difficult to use	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Easy to use**
Non-threatening	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Threatening**
Decrease productivity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Increase productivity**

Your attitude towards computer simulation models.
Please circle the number for each pair of adjectives that best reflects your opinion about computer simulation models. Think of computer simulation models in general terms.

Restrain creativity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Enhance creativity**
Helpful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Harmful**
Enjoyable to use	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Frustrating to use**
Boring	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Intriguing**
A sound investment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**A waste of money**
Difficult to use	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Easy to use**
Non-threatening	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Threatening**
Decrease productivity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Increase productivity**

Thank you very much for your participation!

Appendix 2: Pre-test questionnaires of the control group

Questionnaire

Dear participant,

Thanks for taking the time to fill out this questionnaire. This questionnaire aims to determine your knowledge of commonly used policy instruments in Belgian fisheries, as well as your attitude toward them and your behaviour in relation to these instruments. Please answer these questions completely and truthfully. We guarantee that your answers will be treated **anonymously** and that only aggregated data will be included in reports and publications.

NOTE!: Many questions refer to the terms ‚fisheries system', ‚policy instruments' and ‚sub fleet'.

- *The term ‚fisheries system' includes (i) the Belgian fishing fleet and its overall performance, (ii) fish stocks, and (iii) governmental issues (both national and European) concerning fisheries.*
- *The term ‚policy instruments' refers to the group of instruments policy maker can use to manage the Belgian fisheries system. This group of instruments consists of (1) total quota, (2) the allocation of the total quota over Belgian's five sub fleets, (3) maximum fishing days per vessel, (4) maximum catch per fishing day, (5) licences, (6) decommissioning fees, (7) investment subsidies, and (8) fuel subsidies and taxes.*
- *The term ‚sub fleet' means a grouping of vessels with similar vessel characteristics, fishing method and target species.*

Your personal characteristics

Your gender:	Male	Female
	☐	☐

Your age:	0-25	26-35	36-45	46-55	56-65	65+
	☐	☐	☐	☐	☐	☐

Your work :		
	Owner or captain of a boat	☐
	ILVO	☐
	The Department of Agriculture and Fisheries of the Flemish Government	☐
	The Cabinet of the Flemish Government in charge of sea fisheries	☐
	DG Maritime Affairs and Fisheries of the EU	☐
	Cabinet of Commissioner Joe Borg	☐
	De Redercentrale	☐

Your knowledge about the effects policy instruments have on the fisheries system.

Please circle the number that best indicates how much you agree or disagree with each of the following propositions.

	Strongly disagree			**Neither agree nor disagree**			**Strongly agree**
I know pretty much about the effects policy instruments have on the fisheries system.	1	2	3	4	5	6	7
I do not feel very knowledgeable about the effects policy instruments have on the fisheries system.	1	2	3	4	5	6	7
Among my close colleagues, I am one of the "experts" on assessing the effects of policy instruments on the fisheries system.	1	2	3	4	5	6	7
Compared to most other people, I know less about the effect policy instruments	1	2	3	4	5	6	7

have on the fisheries system.	
When it comes to the impact policy instruments have on the fisheries system, I really do not know a lot.	1 2 3 4 5 6 7

Your attitude towards policy instruments.

For each proposition, four pairs of adjectives are given. Please circle the number for each pair of adjectives that best reflects your opinion about the proposition.

Limiting total catches of a fleet through total quota is ……………………………………………...... for the fisheries system.

Harmful	1	2	3	4	5	6	7	Beneficial
Good	1	2	3	4	5	6	7	Bad
Worthless	1	2	3	4	5	6	7	Valuable
Unfair	1	2	3	4	5	6	7	Fair

Dividing total quota over sub fleets is …………………………………………………………...... for the fisheries system.

Harmful	1	2	3	4	5	6	7	Beneficial
Good	1	2	3	4	5	6	7	Bad
Worthless	1	2	3	4	5	6	7	Useful
Unfair	1	2	3	4	5	6	7	Fair

Limiting the number of fishing days per vessel is ……………….……….………………..…... for the fisheries system.

Harmful	1	2	3	4	5	6	7	Beneficial
Good	1	2	3	4	5	6	7	Bad
Worthless	1	2	3	4	5	6	7	Valuable
Unfair	1	2	3	4	5	6	7	Fair

Limiting the catch per fishing day that a vessel can land is …………………….……………….…. for the fisheries system.

Harmful	1	2	3	4	5	6	7	Beneficial
Good	1	2	3	4	5	6	7	Bad
Worthless	1	2	3	4	5	6	7	Valuable
Unfair	1	2	3	4	5	6	7	Fair

Limiting the amount of vessels in a fleet through licences is ……………………………………... for the fisheries system.

Harmful	1	2	3	4	5	6	7	Beneficial
Good	1	2	3	4	5	6	7	Bad
Worthless	1	2	3	4	5	6	7	Valuable
Unfair	1	2	3	4	5	6	7	Fair

Decommissioning fees are ……………….. for the fisheries system.

Harmful	1	2	3	4	5	6	7	Beneficial
Good	1	2	3	4	5	6	7	Bad
Worthless	1	2	3	4	5	6	7	Valuable
Unfair	1	2	3	4	5	6	7	Fair

Investment subsidies are ……..…………………………………………………………………...... for the fisheries system.

Harmful	1	2	3	4	5	6	7	Beneficial
Good	1	2	3	4	5	6	7	Bad
Worthless	1	2	3	4	5	6	7	Valuable
Unfair	1	2	3	4	5	6	7	Fair

Fuel subsidies are......……………………………………………………………………….…... for the fisheries system.

Harmful	1	2	3	4	5	6	7	Beneficial
Good	1	2	3	4	5	6	7	Bad
Worthless	1	2	3	4	5	6	7	Valuable
Unfair	1	2	3	4	5	6	7	Fair

Fuel taxes are...……………………………………………………………………...………... for the fisheries system.

Harmful	1	2	3	4	5	6	7	Beneficial

Good	1	2	3	4	5	6	7	Bad
Worthless	1	2	3	4	5	6	7	Valuable
Unfair	1	2	3	4	5	6	7	Fair

Your behavioural intentions towards policy instruments.

Please circle the number that best indicates how much you agree or disagree with each of the following propositions.

	Strongly disagree			Neither agree nor disagree			Strongly agree
If I find myself in a position to decide on fisheries management, I **intend** to ...							
... use total quota as a way to manage the fisheries system.	1	2	3	4	5	6	7
... divide the total quota over the sub fleets.	1	2	3	4	5	6	7
... limit the number of fishing days per vessel as a way to manage the fisheries system.	1	2	3	4	5	6	7
... limit the catch per fishing day that a vessel can land as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use licences as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use decommissioning fees as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use investment subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel taxes as a way to manage the fisheries system.	1	2	3	4	5	6	7

Your behavioural intentions towards policy instruments.

Please circle the number that best indicates how likely or unlikely your behaviour for each of the following propositions is.

	Very unlikely			Neither likely nor unlikely			Very likely
If you find yourself in a position to decide on fisheries management, how **likely or unlikely** is it that you would ...							
... use total quota as a way to manage the fisheries system.	1	2	3	4	5	6	7
... divide the total quota over the sub fleets.	1	2	3	4	5	6	7
... limit the number of fishing days per vessel as a way to manage the fisheries system.	1	2	3	4	5	6	7
... limit the catch per fishing day that a vessel can land as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use licences as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use decommissioning fees as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use investment subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel taxes as a way to manage the fisheries system.	1	2	3	4	5	6	7

Your attitude towards computers. *Please circle the number for each pair of adjectives that best reflects your opinion about computers. Think of computers in general terms.*								
Restrain creativity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Enhance creativity**
Helpful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Harmful**
Enjoyable to use	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Frustrating to use**
Boring	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Intriguing**
A sound investment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**A waste of money**
Difficult to use	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Easy to use**
Non-threatening	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Threatening**
Decrease productivity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Increase productivity**

Your attitude towards computer simulation models. *Please circle the number for each pair of adjectives that best reflects your opinion about computer simulation models. Think of computer simulation models in general terms.*								
Restrain creativity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Enhance creativity**
Helpful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Harmful**
Enjoyable to use	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Frustrating to use**
Boring	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Intriguing**
A sound investment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**A waste of money**
Difficult to use	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Easy to use**
Non-threatening	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Threatening**
Decrease productivity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Increase productivity**

Thank you very much for your participation!

Appendix 3: Post-test questionnaires of the experimental group

Questionnaire 2

Dear participant,

Thanks for taking the time to fill out this second questionnaire. This questionnaire aims at evaluating the simulation model and determining your knowledge of commonly used policy instruments in Belgian fisheries, as well as your attitude toward them and your behaviour in relation to these instruments now that you know more about the simulation model. Please answer these questions completely and truthfully. We guarantee that your answers will be treated **anonymously** and that only aggregated data will be included in reports and publications.

NOTE!: Many questions refer to the terms ‚fisheries system', ‚policy instruments' and ‚sub fleet'.

- *The term ‚fisheries system' includes (i) the Belgian fishing fleet and its overall performance, (ii) fish stocks, and (iii) governmental issues (both national and European) concerning fisheries.*
- *The term ‚policy instruments' refers to the group of instruments policy maker can use to manage the Belgian fisheries system. This group of instruments consists of (1) total quota, (2) the allocation of the total quota over Belgium's five sub fleets, (3) maximum fishing days per vessel, (4) maximum catch per fishing day, (5) licences, (6) decommissioning fees, (7) investment subsidies, and (8) fuel subsidies and taxes.*
- *The term ‚sub fleet' means a grouping of vessels with similar vessel characteristics, fishing method and target species.*

Your attitude towards the used simulation model.
Having played with the simulation model, please circle the number for each pair of adjectives that best reflects your opinion about the used simulation model.

Restrain creativity	1	2	3	4	5	6	7	**Enhance creativity**
Helpful	1	2	3	4	5	6	7	**Harmful**
Enjoyable to use	1	2	3	4	5	6	7	**Frustrating to use**
Boring	1	2	3	4	5	6	7	**Intriguing**
A sound investment	1	2	3	4	5	6	7	**A waste of money**
Difficult to use	1	2	3	4	5	6	7	**Easy to use**
Non-threatening	1	2	3	4	5	6	7	**Threatening**
Decrease productivity	1	2	3	4	5	6	7	**Increase productivity**

Policy instruments you have tested during the session.
Please circle the number that best indicates how much you have tested each of the following policy instruments on their effects on the fisheries system.

	Not tested						**Heavily tested**
Total quota	1	2	3	4	5	6	7
Dividing total quota over sub fleets	1	2	3	4	5	6	7
Limiting the number of fishing days per vessel	1	2	3	4	5	6	7
Limiting the catch per fishing day that a vessel can land	1	2	3	4	5	6	7
Licences	1	2	3	4	5	6	7
Decommissioning fees	1	2	3	4	5	6	7

Investment subsidies	1	2	3	4	5	6	7
Fuel subsidies	1	2	3	4	5	6	7
Fuel taxes	1	2	3	4	5	6	7

Validity of the used simulation model.
Please circle the number that best indicates your opinion about the validity of the used simulation model.

Not valid at all 1 2 3 4 5 6 7 8 9 10 Completely valid

Validity of the used simulation model.

Please circle the number that best indicates how much you agree or disagree with each of the following propositions.

	Strongly disagree			Neither agree nor disagree			Strongly agree
The used simulation model behaved logically when playing with it.	1	2	3	4	5	6	7
I had faith in the results of the used simulation model.	1	2	3	4	5	6	7
The used simulation model was an excellent representation of the real Belgian fisheries system.	1	2	3	4	5	6	7
The used simulation model allowed me to learn about the effect policy instruments have on the fisheries system.	1	2	3	4	5	6	7

Learning from the used simulation model.
Please circle the number that best indicates how much you have learned from the use of the simulation model <u>about the effects policy instruments have on the fisheries system</u>.

Learned nothing 1 2 3 4 5 6 7 8 9 10 Learned a lot

Learning from the used simulation model.
Please circle the number that best indicates how much you have learned from the use of the simulation model <u>about how difficult it is to manage a fisheries system</u>.

Learned nothing 1 2 3 4 5 6 7 8 9 10 Learned a lot

Your knowledge about the effects policy instruments have on the fisheries system.

<u>Having played with the simulation model</u>, please circle the number that best indicates how much you <u>now</u> agree or disagree with each of the following propositions.

	Strongly disagree			Neither agree nor disagree			Strongly agree
When it comes to the impact policy instruments have on the fisheries system, I really do not know a lot.	1	2	3	4	5	6	7
Among my close colleagues, I am one of the "experts" on assessing the effects of policy instruments on the fisheries system.	1	2	3	4	5	6	7
I do not feel very knowledgeable about the effects policy instruments have on the fisheries system.	1	2	3	4	5	6	7
I know pretty much about the effects policy instruments have on the fisheries system.	1	2	3	4	5	6	7
Compared to most other people, I know less about the effect policy instruments	1	2	3	4	5	6	7

have on the fisheries system.	

Your attitude towards policy instruments.

For each proposition, four pairs of adjectives are given. *__Having played with the simulation model__, please circle the number for each pair of adjectives that __now__ best reflects your opinion about the proposition.*

Limiting total catches of a fleet through total quota is …………………………………………...... for the fisheries system.

Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Dividing total quota over sub fleets is …………………………………………………………...... for the fisheries system.

Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Limiting the number of fishing days per vessel is ……………….……….…………………..…... for the fisheries system.

Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Limiting the catch per fishing day that a vessel can land is ……………………….……………….…. for the fisheries system.

Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Limiting the amount of vessels in a fleet through licences is ……………………………………..... for the fisheries system.

Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Decommissioning fees are ……………….. for the fisheries system.

Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Investment subsidies are ……..………………………………………………………………...... for the fisheries system.

Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Fuel subsidies are.......……………………………………………………………………….…..... for the fisheries system.

Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Fuel taxes are...…………………………………………………………………………....……….... for the fisheries system.

Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Your behavioural intentions towards policy instruments. *<u>Having played with the simulation model</u>, please circle the number that best indicates how much you <u>now</u> agree or disagree with each of the following propositions.*							
	Strongly disagree			**Neither agree nor disagree**			**Strongly agree**
If I find myself in a position to decide on fisheries management, I **<u>intend</u>** to ...							
... use total quota as a way to manage the fisheries system.	1	2	3	4	5	6	7
... divide the total quota over the sub fleets.	1	2	3	4	5	6	7
... limit the number of fishing days per vessel as a way to manage the fisheries system.	1	2	3	4	5	6	7
... limit the catch per fishing day that a vessel can land as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use licences as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use decommissioning fees as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use investment subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel taxes as a way to manage the fisheries system.	1	2	3	4	5	6	7

Your behavioural intentions towards policy instruments. *<u>Now that you know more about the simulation model</u>, please circle the number that best indicates how likely or unlikely your behaviour for each of the following propositions <u>now</u> is.*							
	Very unlikely			**Neither likely nor unlikely**			**Very likely**
If you find yourself in a position to decide on fisheries management, how **<u>likely or unlikely</u>** is it that you would ...							
... use total quota as a way to manage the fisheries system.	1	2	3	4	5	6	7
... divide the total quota over the sub fleets.	1	2	3	4	5	6	7
... limit the number of fishing days per vessel as a way to manage the fisheries system.	1	2	3	4	5	6	7
... limit the catch per fishing day that a vessel can land as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use licences as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use decommissioning fees as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use investment subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel taxes as a way to manage the fisheries system.	1	2	3	4	5	6	7

Your comments and/or suggestions about the used simulation model.

Please feel free to make any comments and/or suggestions about the used simulation model. Your comments are valuable and will be taken into account when further developing this simulation model or other simulation models at ILVO.

Thank you very much for your participation!

Appendix 3: Post-test questionnaires of the experimental group

Questionnaire 2

Dear participant,

Thanks for taking the time to fill out this second questionnaire. This questionnaire aims at evaluating the simulation model and determining your knowledge of commonly used policy instruments in Belgian fisheries, as well as your attitude toward them and your behaviour in relation to these instruments now that you know more about the simulation model. Please answer these questions completely and truthfully. We guarantee that your answers will be treated **anonymously** and that only aggregated data will be included in reports and publications.

NOTE!: Many questions refer to the terms ‚fisheries system', ‚policy instruments' and ‚sub fleet'.

- *The term ‚fisheries system' includes (i) the Belgian fishing fleet and its overall performance, (ii) fish stocks, and (iii) governmental issues (both national and European) concerning fisheries.*
- *The term ‚policy instruments' refers to the group of instruments policy maker can use to manage the Belgian fisheries system. This group of instruments consists of (1) total quota, (2) the allocation of the total quota over Belgium's five sub fleets, (3) maximum fishing days per vessel, (4) maximum catch per fishing day, (5) licences, (6) decommissioning fees, (7) investment subsidies, and (8) fuel subsidies and taxes.*
- *The term ‚sub fleet' means a grouping of vessels with similar vessel characteristics, fishing method and target species.*

Your knowledge about the effects policy instruments have on the fisheries system.
Now that you know more about the simulation model, please circle the number that best indicates how much you now agree or disagree with each of the following propositions.

	Strongly disagree			Neither agree nor disagree			Strongly agree
When it comes to the impact policy instruments have on the fisheries system, I really do not know a lot.	1	2	3	4	5	6	7
Among my close colleagues, I am one of the "experts" on assessing the effects of policy instruments on the fisheries system.	1	2	3	4	5	6	7
I do not feel very knowledgeable about the effects policy instruments have on the fisheries system.	1	2	3	4	5	6	7
I know pretty much about the effects policy instruments have on the fisheries system.	1	2	3	4	5	6	7
Compared to most other people, I know less about the effect policy instruments have on the fisheries system.	1	2	3	4	5	6	7

Your attitude towards policy instruments.
For each proposition, four pairs of adjectives are given. Now that you know more about the simulation model, please circle the number for each pair of adjectives that now best reflects your opinion about the proposition.

Limiting total catches of a fleet through total quota is …………………………………………..... for the fisheries system.

Worthless	1	2	3	4	5	6	7	**Valuable**
Unfair	1	2	3	4	5	6	7	**Fair**
Harmful	1	2	3	4	5	6	7	**Beneficial**
Good	1	2	3	4	5	6	7	**Bad**

Dividing total quota over sub fleets is ………………………………………………………………...... for the fisheries system.								
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Limiting the number of fishing days per vessel is ……………….……….…………………..….. for the fisheries system.								
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Limiting the catch per fishing day that a vessel can land is …………………….………………..... for the fisheries system.								
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Limiting the amount of vessels in a fleet through licences is ……………………………………..... for the fisheries system.								
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Decommissioning fees are ……………….. for the fisheries system.								
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Investment subsidies are ……..………………………………………………………………...... for the fisheries system.								
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Fuel subsidies are.......…………………………………………………………………….…..... for the fisheries system.								
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Fuel taxes are...………………………………………………………………………...………..... for the fisheries system.								
Worthless	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Valuable**
Unfair	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Fair**
Harmful	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Beneficial**
Good	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Bad**

Your behavioural intentions towards policy instruments.

Now that you know more about the simulation model, please circle the number that best indicates how much you now agree or disagree with each of the following propositions.

	Strongly disagree			Neither agree nor disagree			Strongly agree
If I find myself in a position to decide on fisheries management, I **intend** to ...							
... use total quota as a way to manage the fisheries system.	**1**	**2**	**3**	**4**	**5**	**6**	**7**

... divide the total quota over the sub fleets.	1	2	3	4	5	6	7
... limit the number of fishing days per vessel as a way to manage the fisheries system.	1	2	3	4	5	6	7
... limit the catch per fishing day that a vessel can land as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use licences as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use decommissioning fees as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use investment subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel taxes as a way to manage the fisheries system.	1	2	3	4	5	6	7

Your behavioural intentions towards policy instruments.

Now that you know more about the simulation model, please circle the number that best indicates how likely or unlikely your behaviour for each of the following propositions now is.

	Very unlikely			Neither likely nor unlikely			Very likely
If you find yourself in a position to decide on fisheries management, how **likely or unlikely** is it that you would ...							
... use total quota as a way to manage the fisheries system.	1	2	3	4	5	6	7
... divide the total quota over the sub fleets.	1	2	3	4	5	6	7
... limit the number of fishing days per vessel as a way to manage the fisheries system.	1	2	3	4	5	6	7
... limit the catch per fishing day that a vessel can land as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use licences as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use decommissioning fees as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use investment subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel subsidies as a way to manage the fisheries system.	1	2	3	4	5	6	7
... use fuel taxes as a way to manage the fisheries system.	1	2	3	4	5	6	7

Your comments and/or suggestions about the proposed simulation model.

Please feel free to make any comments and/or suggestions about the proposed simulation model. Your comments and/or suggestions are valuable and will be taken into account when further developing this simulation model or other simulation models at ILVO.

Thank you very much for your participation!

Photo: Jay Forrester and me at the 25th International Conference of the System Dynamics Society and 50th Anniversary Celebration


Jay
Hendrik

Chapter 6: General conclusions

This thesis describes the process of developing a microworld in which fisheries policy initiatives can be visualised and rehearsed (Morecroft, 1999). It first presents insights into the real fisheries system and determines whether the theory of strategic groups is relevant for the Belgian fishing fleet. These findings are then used to develop a microworld in which stakeholders can "play" and discover the long term effects that policy instruments may have on the Belgian fisheries system. This makes the microworld a useful instrument to test whether policymakers have the policy instruments at their disposal to align the real fisheries system with their desired one. Because this microworld has been developed following a "create-and-share"-approach (Kreutzer, 1995: 218), the last part of this thesis is about reaching and informing a group larger than the model-development team about the outcomes. This is done, in tandem with a true experiment in which we test if stakeholders in the Belgian fisheries system actually learn from our microworld. Such a test of learning is seen as the ultimate criterion for assessing the validity of microworlds (Morecroft, 2008).

This concluding chapter begins with a synopsis of the answers to the research questions identified in Chapter 1. Second, the main findings and contributions of this thesis are listed, further discussed and translated into policy recommendations. Then follows a discussion of the limitations of this thesis and this chapter ends by pointing out avenues for future research.

6.1 Answering the research questions

This thesis addresses four research questions (Figure 6.1).

1. ***Do firms in the Belgian fishing industry cluster around a limited array of competitive strategies (i.e., strategic groups) that result in performance differences?***

This research question determines if intra-industry groupings need to be taken into account when developing our microworld which is important if the industry does not consist of strategically homogenous agents. Clearly, the answer is yes. Chapter 2 defines five strategic groups in the Belgian fishing fleet that have clearly distinct performance outcomes on financial, operational and overall performance measures. These strategic groups are derived through clustering firms based on their state of resources, built up through the collection of their past competitive strategic decisions, which are perceived as the main sources of mobility barriers in the fishing industry, namely: (1) technology, (2) product range and (3) geographic reach. Highly valid cluster solutions are obtained through use of excessive within- and between-method triangulation (Ketchen *et al.*, 1996). Following this method, the five identified strategic groups are (1) *the large beam trawler fleet*: vessels with high-powered engines, enabling them to cover all of the Belgian fishing grounds, operate the beam trawl and land the highest variety of species; (2) *the small beam trawler fleet*: vessels similar to the large beam trawlers but with significantly less engine power and slightly less diverse landings; (3) *the shrimp beam trawler fleet*: vessels similar to the small beam trawlers but slightly less powerful and heavily specialised towards landing brown shrimp; (4) *the otter trawler fleet*: vessels which differ from the small beam trawler fleet in that they operate the otter trawl, which results in a slightly less mixed product range; and (5) *the trammel netter fleet*: vessels operating passive fishing methods specialised in just a few species comparable to the span in product range of the shrimp beam trawlers.

2. ***Do firms in the Belgian fishing industry stick to their competitive strategy in the long term?***

Investigating whether the firms stick to their competitive strategy in the long run allows us to omit "firm-movement" (Fiegenbaum *et al.*, 1993: 75) between groups from the microworld. This drastically simplifies the microworld. This research question can be answered in the affirmative, according to the findings presented in Chapter 2. Once a vessel has decided on its strategic position in the fishing industry (i.e., the strategic group), in 80% of the cases, it stays in that position for a significant amount of time (in this case ten years). However, not every strategic group enjoys this high level of group loyalty, since firm-movement differs significantly between the strategic groups. The large beam trawler fleet is the strategic group whose group members shift the least, whereas small beam trawlers shift the most. Firm-movement between small beam trawlers and shrimp beam trawlers is also high. However, the strategic group of the shrimp beam trawlers has more stable memberships compared to the small beam trawlers. The shrimp beam trawlers, together with the trammel netters, are the second most stable strategic groups. Finally, like the small beam trawlers, the otter trawlers also encounters important fluctuations in firm-movement but those otter trawlers do not have a "second best option" like the "small beam trawlers-shrimp beam trawler"-trade off. The analysis performed to obtain these results is based on simple counts and percentages of firm-movement, where "firm-movement" is defined as "cluster analytic assignment of a firm to a different group than it had been in during the prior year" (Mascarenhas, 1989: 346).

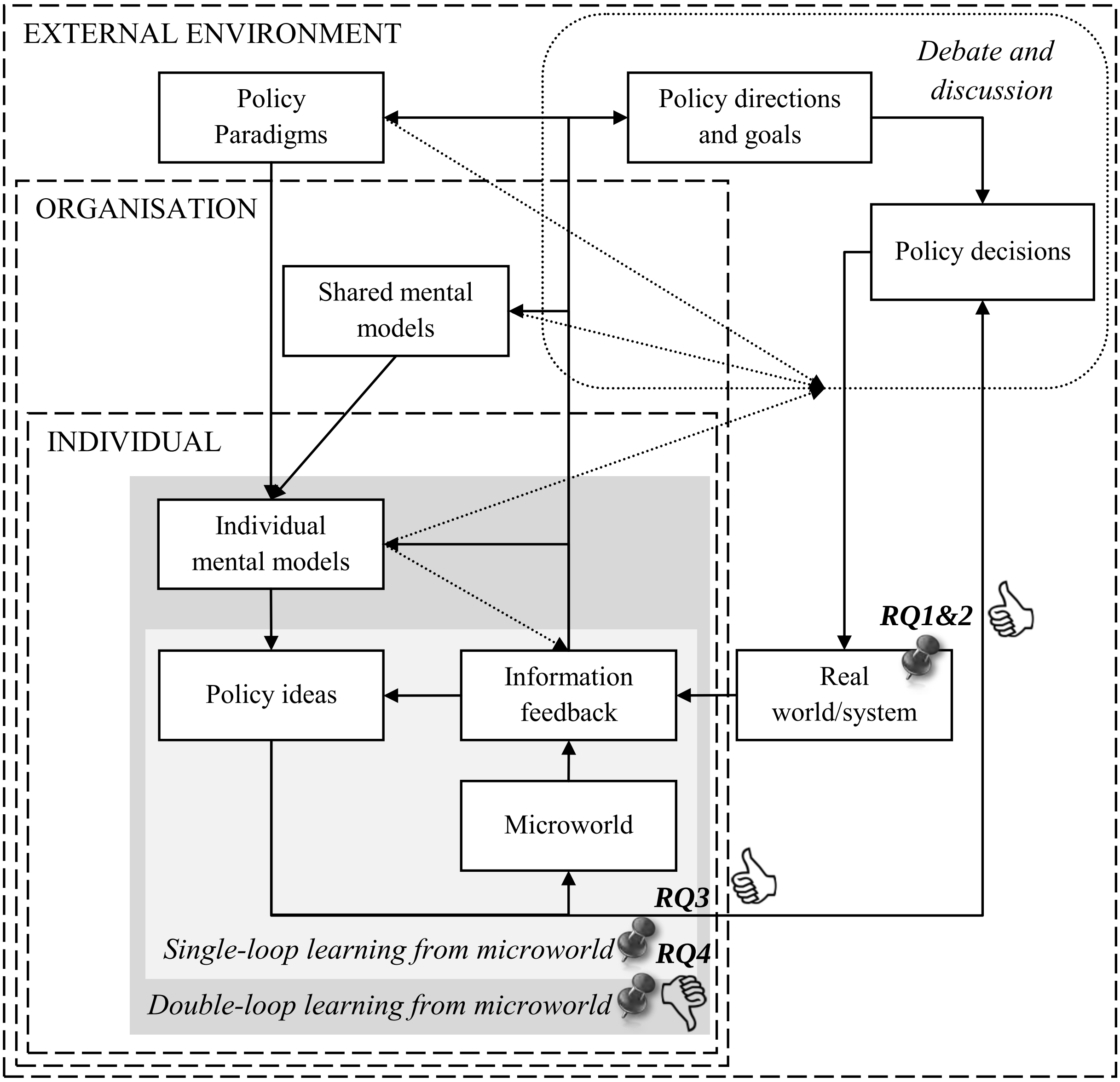
3. ***Do policymakers have the policy instruments at hand to align the real fisheries world with the desired world of their individual mental models?***

This research question can be answered in the affirmative, as Chapter 4 illustrates. Running multiple scenarios in our microworld clearly shows that policymakers in Belgian fisheries have the policy instruments at hand to install management systems that are able to meet four realistic but totally different management objective functions (social welfare functions). These four objective functions are labelled: (1) "a bigger industry is a better industry", (2) "small but wealthy", (3) "keep them quiet and satisfied at low expenses" and (4) "let's go green". These different management objective functions serve the purpose of reflecting possible differences in policymakers' desired states of the fisheries system (part of their individual mental models). This study also vividly illustrates that policymakers should be aware of counterintuitive and surprising outcomes in their attempts to align the real fisheries world with their desired one. Counterintuitive behaviour of the fisheries system is a frequently returning observation and mainly occurs due to "misperceptions of feedback" (Atkins *et al.*, 2002; Diehl *et al.*, 1995; Sterman, 1989).

4. Do stakeholders learn (differently) from playing with microworlds?

This research question must be answered negatively*,* since Chapter 5 concludes that the three main stakeholder groups of the Belgian fisheries system, i.e., (1) policymakers, (2) scientists and (3) ship owners and skippers, have not learned about the effect policy instruments have on the fisheries system from playing in the microworld. This surprising outcome contradicts all of the stakeholder groups' subjective reports about having learned from the microworld. They all stated that they learned about the effect policy instruments have on the fisheries system, that they have confidence in the microworld and perceived its behaviour as valid. This study cannot confirm that individual double-loop learning from microworlds occurs. These results are based on a strictly controlled "before-after with control group"-experiment in which 57 stakeholders (i.e., 25 policymakers, 20 scientists and 12 ship owners or skippers) participated, where learning is conceptualised as a process altering knowledge, attitude and behaviour (i.e., parts of the individual mental model).

Figure 6.1: Summary of the answers to the research question visualising what this dissertation has covered from its underlying conceptual framework ("thumbs up" and "thumbs down" means a "positive" and "negative" answer to the research question, respectively)



(Source: Own compilation, composed of Kim, 1993b; Kunc *et al.*, 2006; Morecroft, 1984; Sterman, 2000)

6.2 Findings, contributions and policy recommendations

The findings, contributions and policy recommendations of this thesis are related to its three main topics: (1) strategic groups in the Belgian fisheries industry, (2) outcomes from the microworld of the Belgian fisheries system, and (3) measuring whether learning occurred from playing in the microworld.

6.2.1 *Strategic groups in the Belgian fisheries industry.*

This research on strategic groups in Belgian fisheries borrows the concept of strategic groups, together with its theory from the field of strategic management, and applies it for the first time to the field of fisheries management science. The aim is to test whether strategic group theory is of value to determine intra-industry groupings in the Belgian fishing fleet based on different orientations in the vessels' competitive strategies. Following Colquitt and Zapata-Phelan's (2007) classification on theoretical contributions of empirical research, this study is classified as a theory "tester" and therefore contributes to the further generalisation of strategic group theory. Strategic group theory is shown to be valuable to determine intra-industry groupings within the Belgian fishing fleet. It discovers the existence of five strategic groups based on the differences in their state in resource configurations; this reflects a firm's past strategic investments resulting from the different choices in past competitive strategies. This study also finds a link between group membership and performance; different strategic groups have different performance levels on different financial, operational and overall performance measures (Venkatraman *et al.*, 1986). This is no sinecure, since strategic group research is still unable to consistently find this "group membership-performance link" (Cool *et al.*, 1988; Ketchen *et al.*, 1997). Therefore, this finding contributes to generalising the "group membership-performance link" to a new industry.

This study also shows that these five strategic groups are very stable over time, revealing limited firm-movement among strategic groups over time. This indicates that the differences in the state of resource configurations among these strategic groups are most likely important sources of mobility barriers and thus also sources of competitive advantage within the Belgian fishing industry. As a result, these findings support the theory of the existence of mobility barriers between strategic groups. However, not every strategic group has the same high level of group loyalty, which indicates that these mobility barriers are "asymmetric" (Caves *et al.*, 1977; Harrigan, 1985; Hatten *et al.*, 1987). This implies that not all mobility barriers between strategic groups are equally high. Some shifts between strategic groups are more easily made because the resource(s) required are not too costly or risky. The results on the average yearly firm movement across strategic groups between pairs of adjacent years illustrated different firm movement patters for different strategic groups. Unloyal small beam trawlers move to the shrimp beam trawler fleet. The inverse patter can be observed for the unloyal shrimp beam trawler. Hence, there is back-and-forth-movement between these two strategic groups. Unloyal otter trawlers move to both the small beam trawler fleet and shrimp beam trawler fleet, but inverse movement is only marginally observed. It seems therefore that vessels which have made the shift towards the otter trawler fleet are satisfied with their new strategic direction. Finally, the results of average yearly firm movement across strategic groups illustrates that all other potential firm movement patters between the strategic groups are marginal or absent. This illustrate that certain shifts are (too) costly or risky. Additionally, and probably even more important in explaining these absent or marginal firm-movements is what Rumelt (1984) refers to as a firm's "isolating mechanisms". Isolating mechanisms represent "firm specific commitments (i.e., resources) that restrict the individual firm's degrees of strategic freedom and thus may prevent a firm from switching from one strategy to another" (Leask *et al.*, 2005: 459). This is for instance the case for the current trammel netting fleet in Belgium. These vessels are often catamarans that have not the capability to tow fishing gear over the sea-bed. Hence, their past strategic decisions have isolated them from any form of beam- or otter trawling. This clearly limits their strategic freedom.

This study on strategic groups in Belgian fisheries is of practical relevance to both policymakers and ship owners. We recommend that policymakers consider strategic group theory as a way to simplify fisheries management, along with its regulation. Strategic group theory gives insight into "which firms compete strongly with each other" (Fiegenbaum *et al.*, 1988: 21). Knowing the strategic differences between firms and the patterns of rivalry between firms within the same industry is crucial when managing fisheries and implementing public policies (Oster, 1982: 376). Therefore, strategic groups should form the basis for developing regulation instead of using (1) tremendously detailed typologies of sub fleets solely based on technical characteristics (i.e., fishing methods, gear modifications and mesh sizes) (EC, 2002) or (2) overly specified classification systems based on métiers (EC, 2008) which probably need simplification (i.e., aggregation of métiers in fleet segments) to become practical. This strategic group approach could result in a more strategic form of regulation, meaning that the regulation will be more focused on (1) affecting strategic groups' competitive advantages (i.e., mobility barriers), (2) affecting "isolating mechanisms" of firms, and (3) managing rivalry between strategic groups. In addition, this will shrink the number of policy instruments required to regulate fisheries. Introducing strategic group theory to fisheries management can be a useful way to reengineer and simplify the current Common Fisheries Policy of the European Union.

Ship owners and skippers can use the results of this study on performance differences between these strategic groups to determine if they are still satisfied with their current strategic direction. If so, they can compare their performance to the average performance of their group peers. If not, this study unveils the different performance potentials for the different competitive strategies in the current industry. Ship owners and skippers can thus use these results to reflect on current business and change strategic course based on various performance indicators.

Finally, this study has also implications for research, since it has applied and tested the rigid methodological approach of Ketchen and Shook (1996) in identifying clusters in strategic management research. Their approach tackles the main weakness of cluster analysis' reliance on researcher judgment, which subjects the validity of results to serious doubts. Ketchen and Shook (1996) believe that the key to surmounting this problem is the vigorous pursuit of both within- and between-method triangulation (Ketchen *et al.*, 1996). Our study has illustrated that this practice leads indeed to highly valid cluster solutions. Therefore, future researchers should rigorously implement this approach.

6.2.2 Outcomes from the microworld of the Belgian fisheries system

The microworld developed in this thesis serves the purpose of a learning laboratory for the ex ante evaluation of possible policy strategies in Belgian fisheries management. Hence, the outcomes of this microworld should not be interpreted as (exact) quantitative predictions of the future. Instead, the microworld should be used to learn more about the dynamic complexity of the fisheries system and options for fisheries management. Microworlds, as compared to the real world, offer a risk-free (Garvin, 2000; Keys *et al.*, 1996; Kofman *et al.*, 1993; Senge, 1996) and controlled (Kim, 1995) environment in which policy strategies can be rehearsed and evaluated much faster than in real time (De Geus, 1997; Sterman, 2000). Based on these "rehearsing possibilities", we have used our microworld to test if different configurations of the current policy instruments of the Belgian fisheries management system can be used to meet different management objective functions. The results of this study are positive as long as the interdependencies and often conflicting nature between objectives were taken into account when defining objective functions. Additionally, counterintuitive or surprising outcomes can and do occur in the microworld. Such outcomes are the result of "misperceptions of feedback" that occur when people's mental models are deficient in understanding the dynamic complexity of the system they are trying to manage (Sterman, 2000). Therefore, we recommend using a form of simulation (such as our microworld) to test policy changes ex ante before implementing them in the real fisheries system. This practice would significantly limit the risk of implementing policies in the real fishing system that could result in unexpected and/or undesired outcomes. Playing in microworlds should "anticipate surprises" (Morecroft, 1984: 224). This study also illustrates the need for finding the right balance in combining policy instruments when attempting to best meet predefined management objectives, as the omission of certain policy instruments from the policy strategy can result in negative outcomes. This thesis, like the study of Greiner *et al.* (2000), asserts that it is very unlikely for one single policy instrument to be capable of solving a complex problem. Instead, the right mixture of policy instruments is necessary to achieve the desired outcome. Our microworld allows testing several possible mixtures. Finally, with some (small) changes to the microworld, other policy instruments or management systems outside the scope of the current microworld can be tested. For instance, replacing the common pool quota system of the microworld by an individual transferable quota system (ITQ) will allow comparing, ex ante, a whole different management system for its effects on the Belgian fisheries system. Our microworld certainly has a future role in advising fisheries policymakers, though this advice will not take the form of concrete answers to concrete problems. Instead, it will unveil the dynamic complexity of the fisheries system and prepare policymakers for alternative futures by bringing these futures to life. Moreover, our microworld can also enrich and/or perhaps even change policymakers' interpretation of the complex fisheries world (in other words, affect their mental models). However, effective and efficient ways in which mental models could be enriched and/or changed through the application of microworlds are still subject to speculation.

With the development and application of our microworld, we have introduced system dynamics to the Belgian fisheries research agenda and more specifically to the research agenda of the Institute for Agriculture and Fisheries Research (ILVO)[3]. This was an important step for ILVO, since ILVO researchers are seeking to give simulation models a central role in formulating a long-term strategy for the Belgian fisheries system (Polet *et al.*, 2006). Our microworld has indeed proven very valuable since ILVO has learned more about options for fisheries management through playing in it. This is essential since Belgian fisheries are still, like many other fisheries, subject to mismanagement of varying proportions (Arnason, 2009). We also recommend using our microworld among various stakeholder groups within the fisheries industry. It can serve as a transitional object to spur debate and discussion of different strategies for the Belgian fisheries system (Morecroft, 1984). We believe these debates and discussions to be a key to enhancing the mutual understanding of the problems various stakeholder groups are currently facing. Such mutual understanding is crucial when developing a strategy for the future that is acceptable for all stakeholder groups. A first step towards this direction has already been taken; the Directorate-General of Maritime Affaires and Fisheries of the European Commission (DG MARE) has invited us to elaborate on its future value for the European Commission. We suggest creating a platform in which our microworld (and others) can serve as a transitional object while discussing potential fisheries management options. We also recommend using our microworld (and others) as a tool to introduce new recruits to the dynamic complexity of fisheries and options for management. It can also serve them when discussing options for fisheries management with senior staff.

Our microworld can also be used for education. Besides introducing our microworld to actual decision makers or new recruits dealing with fisheries management issues, our microworld can also be of value to (university) courses related to fisheries management and even natural resource management. In these courses, our microworld can illustrate to students (1) the interlocking feedback loops between the fisheries system and the fisheries management system, (2) the short- and long-term effects policy instruments have on the fisheries system, (3) the interdependences and often conflicting nature of the different management objectives in fisheries management, and (4) counterintuitive outcomes in fisheries management due to misperception of feedback. In addition to these illustrative purposes, it can also be used to enhance and enrich debates and discussions (in small groups and/or through teacher-student interactions) about options for fisheries management. Last but far from least, our microworld gives students the opportunity to experience what it is to manage fisheries systems in real life through play. Teachers can use our microworld in combination with other complementary microworlds about fisheries- and natural resource management. Other such microworlds are: (1) Fish Banks, Ltd (Meadows *et al.*, 2001) on how rivalry of competing fisheries affects the sustainability of renewable natural resources; (2) Moxnes' (1998a; 1998b) microworld on the exploitation of a single cod population in an isolated Norwegian fjord which teaches us that not only "tragedy of the commons" but also "misperception of feedback" results in overexploitation; and (3) Morecroft's (2008; 2007) microworld called "fish and ships" which deals with the puzzling dynamics of fisheries when managing fishing effort.

[3] www.ilvo.vlaanderen.be

6.2.3 Measurement of learning from the microworld

Following Colquitt and Zapata-Phelan's (2007) classification of theoretic contributions of empirical research, this study is classified as a theory "tester" since it tests the highly important axiomatic belief in individual and organisational learning theory that decision makers do learn from using microworlds. However, our research does not prove that this is the case, at least not for decision makers who are not involved in the modelling process itself. The three main stakeholder groups of the Belgian fisheries system (policymakers, scientists and ship owners and skippers) did not learn from playing with our microworld about the effect policy instruments have on the fisheries system. This outcome contradicts the stakeholders' subjective report that they learned from the microworld about the effect policy instruments have on the fisheries system. They further stated that they have confidence in the microworld and perceived its behaviour as valid. Therefore, we must conclude that our "create-and-share"-approach (Kreutzer, 1995: 218) to developing a microworld has not resulted in double-loop learning outside of the modelling team.

Similar studies, although often performed with students, come to similar conclusions of participants not learning from microworlds (e.g., Cameron *et al.*, 2005; Drappa *et al.*, 2000; Ellis *et al.*, 2005; Gresse von Wangenheim *et al.*, 2009; Pfahl *et al.*, 2001; Thomas *et al.*, 1991). This leads us to wonder whether "experience is the best teacher" (Wolfe, 1975a: 450) in simulation tasks that involve solving dynamic and complex problems. Several studies have concluded that experiential learning is so unstructured that the knowledge gained may be fragmentary and haphazard (e.g., Bell *et al.*, 2002; Brown, 2001; DeRouin *et al.*, 2004; Ely *et al.*, 2007; Reeves, 1993; Wolfe, 1975a). Further, there is no assurance that the participants even learn the "right" thing (Drappa *et al.*, 2000). As a result, the participants' interactions with the microworld should become more structured in order to obtain (or increase) learning effects (Bell *et al.*, 2008; Wolfe, 1975a). Increasing learner control in this way may be an important challenge facing simulation-based training design. Effective guidance and support strategies for learning need to be identified and embedded in the design of simulation-based training (Bell *et al.*, 2008; Cannon-Bowers *et al.*, 2009; Wolfe, 1975a). However, it is our belief, together with many researchers, that guidance alone is not sufficient. It seems that the true value of microworlds lies within their capability to rehearse and visualise strategies (Morecroft, 1999) so they can be brought into debate and discussion (Morecroft, 1984) among stakeholders. This idea is backed by the study of Dill *et al.* (1963), which found that students remembered more vividly what they had learned from the interactions with other people than what they had learned from playing with the microworld. Hence, it seems that some form of human interaction, not only through guidance, is required in order to learn from microworlds (Bell *et al.*, 2008).

Although there are researchers who go one step further and believe that a certain form of "classroom atmosphere" or "learning community" is essential for learning (Katz, 1999; Webster *et al.*, 1997), there are others (i.e., the naturalistic decision making movement) who argue that it is exactly this often unfamiliar and unrealistic "classroom/laboratory atmosphere" which limits learning (Sweeney *et al.*, 2000). They believe people can perform well in familiar, naturalistic settings yet perform the same type of task poorly in unfamiliar laboratory or training settings. Therefore, it is not clear yet to what extent the environmental context affects learning outcomes. Some also advocate group model building (e.g., Rouwette *et al.*, 2002; Vennix, 1990; Vennix, 1996). This group claims that decision makers must be actively involved from the beginning of the modelling process in order to learn from a microworld (Pfahl *et al.*, 2004; Warren *et al.*, 1999). If they are not involved, the task of the modeller becomes much harder, and the likelihood of learning together with the implementation of the results is diminished (Richardson *et al.*, 1999: 355). Group model building makes sense, but its main downside is its requirement of a vast number of different resources (i.e., skills, time, money, people, etc.). As a result, most modelling exercises still do not follow the principles of group model building. In the future, these resource limitations will most likely remain an obstacle in the development of other microworlds based on group model building. It is thus vital that research on learning from microworlds is not exclusively focused on learning from microworlds in group model building processes.

6.3 Limitations

This thesis bundles different research topics that have distinct designs and methods. Because of this, most of its limitations are research-topic related and can thus be found in each relevant chapter. We therefore discuss three more general limitations of this dissertation.

6.3.1 Generalisation of the results

The research findings above are not assumed to be universally applicable, mainly because this thesis is based on a single case study of the Belgian fisheries system. The study on strategic groups and the microworld and its outcomes both have limited timeframes. As for the outcomes of the microworld on the alignment of the real fisheries world with the desired world embedded in the policymaker's mental models through applying policy instruments, a nearly infinite number of mental models exist. This limits the possible generalisation of these outcomes. Last, generalising the results of the experiment about learning from our microworld is limited not only due by the Belgian scope, but also by the characteristics of our microworld itself and the rather small sample size used. Hence, a case-by-case basis will reveal whether our results can be generalised. This implies that for the results related to our strategic group study, there may be many more strategic groups beyond both (1) the geographic borders of the Belgian fisheries industry and (2) the ten-year timeframe of this study. Even the resources perceived to be the main sources of mobility barriers in the fishing industry can vary (slightly) in different empirical settings. Finally, the performance differences observed in our study may also be significantly different according to the differences in the external environment in which these groups operate. Nevertheless, the approach to defining strategic groups together with its underlying theory and methodology can be applied beyond the Belgian context. The microworld and its outcomes are more general than our study on strategic groups, as it is a theoretical microworld however grounded in empirical research and findings of the Belgian fisheries system. This means that outcomes generated by the microworld can only be extrapolated to other fisheries systems where conditions are similar to that of the Belgian fisheries system. Following are the most important conditions that should be met for these results to be prevalent across empirical settings. First, since this microworld is all about the effect policy instruments (i.e., the fisheries management system) have on fisheries systems, it is obvious that our results are only applicable to fisheries systems that are managed through a similar form of management system. However, the policy instruments in the Belgian fisheries system are commonly used in many fisheries systems around the globe (Dankel *et al.*, 2008; FAO, 2009b; Sterner, 2003). Second, the Belgian fishing industry is a highly industrialised fleet. Hence, the outcomes of the microworld are more relevant to fisheries systems that have equally industrialised fleets. The value of the results increases even more significantly if similar strategic groups can be identified. This may be the case for North Sea countries, since they have a significant share of beam trawlers. A final condition is the need for similarity in the scale of the fisheries system. The Belgian fisheries industry is a small industry that has no significant impact on most macroeconomic dynamics such as price-fixing. Last, our research on learning from microworlds is in its infancy. The results presented above are only a first contribution to evaluating learning from microworlds. It is unlikely that these results can be generalised. Further research on evaluating learning from microworlds is needed and will be published in due time.

6.3.2 The reliability of the secondary data

Except for the experiment on learning from microworlds, our research is mainly based on secondary data. However, the quality of this data can often be questioned, as data-checks frequently yielded conflicting results. Figures differed repeatedly across databases and reports from different institutions. Further inquiry into these databases also unveiled that conflicting data had been saved on occasion. For instance, queries sometimes produced a catch for a certain vessel in a certain area at a certain time but no complementary fishing effort. The accounting data was the most strikingly unreliable. Beside the voluntary nature of the data gathering, which definitely biases the data, we also regularly found discrepancies between the accounting data reported in these annual surveys and account data stated in the annual balance sheets of the shipping companies. Nevertheless, we had no choice but to use the data collected from these surveys as the few actual balance sheets we were able to collect were not representative of the whole industry. Note, however, that the purpose of this discussion is not to assign blame; it is simply to illustrate that the only data we could find had different degrees of reliability. We always made decisions that reduced these practices to an absolute minimum, although sources for data triangulation are rather limited.

6.4 Directions for future research

This final section highlights potential avenues for future research. Although some of the previous chapters have already suggested some directions for future research, it is now our intention to point at research directions relate to the overall theme of this dissertation: directions for progress on the state of the art of learning from microworlds.

This dissertation has emerged from the absence of a well structured body of evaluation research that examines whether any valuable "learning" takes place from the use of microworlds (Akili, 2007; Bakken *et al.*, 1994; Bell *et al.*, 2008; Cavaleri *et al.*, 1997; Gosen *et al.*, 2004; Gresse von Wangenheim *et al.*, 2009; Huz *et al.*, 1997; Raia, 1966; Sweeney *et al.*, 2000; Tonks *et al.*, 1997; Wolfe, 1976). The research presented here is, at its current stage, a first contribution to evaluating learning from microworlds. But this study did not reveal evidence that decision makers learn from using microworlds. This suggests that more work is needed to fully realize the potential of microworlds in learning processes. Yet researchers are left with little guidance on how to develop an effective "learning system", because the factors that influence the effectiveness of simulation-based training remain unclear (Bell *et al.*, 2008). One possible avenue for future research is to replicate our experiment in similar and/or different settings. Although such scientific research may be viewed as less valuable, the authors believe it is the only way to yield more generalised results in the future since, as in our study, research evaluating learning from microworlds typically has small sample sizes (e.g., Cavaleri *et al.*, 1997; Drappa *et al.*, 2000; Gresse von Wangenheim *et al.*, 2009; Hung, 2008; Huz *et al.*, 1997; Pfahl *et al.*, 2001; Pfahl *et al.*, 2004; Sindre *et al.*, 2009). Replication would validate our results and further contribute to the "who", "where" and "when" (i.e., the temporal and contextual factors) (Whetten, 1989) of the theory of learning from microworlds.

Further, we recommend continuing to use experimental evaluation research in a quest to determine learning from microworlds. However, instead of testing if using microworlds result in learning, future research should focus more on testing which features of microworlds are essential to generate learning outcomes. These tests should also be combined with tests to determine which characteristics of the "users" and the "situation" (i.e., learning environment including guidance, human interactions, shared mental models and paradigms; see "conceptual framework" above) are essential for learning to occur from microworlds (Bell *et al.*, 2008; Größler, 2004). Related to the features of the microworld, research should for instance test if differences in (1) scope, (2) level of dynamic complexity, (3) level of detailed complexity, or (4) user-friendliness of the interface of the microworld generate differences in learning outcomes. Related to the characteristics of the user, research should test if differences in (1) education, (2) job function, (3) age, (4) socioeconomic status (SES), (5) attitude towards microworlds, (6) attitude towards computers, or (7) attitude towards training results in differences in learning outcomes. Finally, relevant research questions related to the differences in situation are: (1) Do organisational shared mental models affect individual learning from microworlds?; (2) Does playing the microworld in teams instead of playing it individually result in better learning effects?, (3) Does learning from microworlds increase with the intensification (i.e., duration, number of sessions) of simulation-based training?, and (4) Is group model building the best (or perhaps only) way to obtain learning effects from microworlds?

We recommend that these tests be performed only in rigidly controlled "before-after with control group"-experiments in which the experimental group(s) only differ(s) from the control group by exactly one characteristic of the microworld, users or situation (Größler, 2001; Pfahl *et al.*, 2004). We believe that this form of experimental design is the only one that is able to causally link the observed learning effects to characteristics of the microworld, users or situation in a way that rules out all alternative hypotheses.

Next, following Bell et al. (2008), we also recommend adoption of a more "process-based approach" to evaluating learning from microworlds. It is our belief that future research on the subject would be more effective if it would examine the actual processes or mechanisms that explain learning effects from these microworlds (i.e., a form of deutero-learning from microworlds). This would reveal the effect on learning of the following: the way in which (1) policy ideas are tested through the microworld (for instance: structured versus unstructured testing), (2) information feedback is presented/communicated by the microworld, and (3) information feedback is understood, interpreted and analysed by the subject using the microworld. Additionally, this would also make it possible to visualise how different characteristics of the microworld, users or situation affect these processes. Such insights would lead to strategies for increasing learning from microworlds.

One last suggestion for future evaluation research on the efficacy of microworlds in learning processes is to assess whether, and how, these microworlds affect the actual behaviour and performance of its participants. Hence, research should not only be limited to discovering changes in participant's attitudes, thinking, skills and behavioural intentions (Sweeney *et al.*, 2000). Instead, future research should investigate how learning effects from microworlds can be transferred (more) effectively to the real system. How they can improve performance in similar real-life situations? In our case, this means how learning from our microworld about the effect policy instruments have on the fisheries system can be included in more effective and efficient fisheries management.

We end this thesis with the recommendation that (small-scale) tests of learning should become mandatory in every study that uses simulation models as learning laboratories. These tests could take the form of a (small) evaluation survey and/or interview with the subjects who have used the microworld. Such tests are essential for the microworlds used in these studies, because the ultimate goal of a microworld is to stimulate learning. Therefore, learning is also the most important criterion for assessing its validity (Morecroft, 2008). Furthermore, these tests will be a great help in identifying the most urgent needs in future research on learning from microworlds. They will thus speed up the process of scientific inquiry by stimulating development of new theories on learning from microworlds and new subjects to be further rigidly tested.

Photo: I was a visiting PhD-student at London Business School in 2008
It was a great experience!
(©Fany Nan)

Hendrik Stouten - Curriculum Vitae

Hendrik Stouten was born in Ostend on May 5, 1982. He obtained the degree of Master in Political Sciences and the degree of Master in Management for Governmental Organisations, both at Ghent University. In November 2005 he started as a research attaché/doctoral researcher at the Institute of Agricultural and Fisheries Research, Animal Science Unit, Fisheries. Between 2005 and 2010 his research combined the area of fisheries management science with the area of organisational learning. His research was mainly focussed at (1) developing a microworld that serves as a learning laboratory for fisheries management, and (2) investigating the value of these microworlds in thinking about fisheries management strategies. In 2008, he stayed for three months at London Business School as a visiting PhD student during which he participated in advanced courses on strategy dynamics and strategic modelling. In parallel to his PhD work, he also got involved in national and international projects related to fisheries economics and industrial organisation in fisheries. Finally, he participated in many national and international scientific conferences, seminars and workshops with oral presentations. At the Conference of the European Association of Fisheries Economists in Reykjavik, Iceland, one of his papers was among the best papers in the track "Advances in fisheries analysis and modelling" which was awarded with publication in the journal Aquatic Living Resources.

Articles in peer-reviewed international journals included in the Science Citation Index (A1)

Stouten, H.; Heene, A.; Gellynck, X.. & Polet, H. (2008). The effect of restrictive policy instruments on Belgian fishing fleet dynamics. In: Aquatic Living Resources, 21, 247–258.

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Stouten, H.; Heene, A.; Gellynck, X.. & Polet, H. (2008) Learning from microworlds: evidence from a fisheries simulation game. Poster presented at the 10th VLIZ Young Scientists' Day. Special edition at the occation of 10 years VLIZ, Ostend, Belgium, 27 November 2009.

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Photo: Some of the books I have enjoyed reading during my PhD

By-catch Reduction in the World's Fisheries
Steven J. Kennelly (Ed.)
The Effects of Fishing on Marine Ecosystems and Communities
Hall
Fisheries Biology, Assessment and Management
SECOND EDITION
King
Strategic Management Dynamics
WARREN
WILEY
Science and Sustainable Management of the North Sea: Belgian case studies
Edited by Jan-Bart Calewaert and Frank Maes
Advances in Fisheries Economics
Edited by Bjørndal, Gordon, Arnason and Sumaila
FISH WELFARE
EDITED BY BRANSON
Visserij in cijfers 2009
EV-21
BALANCING IMPACTS OF HUMAN ACTIVITIES IN THE NORTH SEA (BALANS)
SPSD II
150 jaar zeevisserijbeheer 1830-1980
IIFET 2006 Portsmouth – Book of Abstracts
COMMERCIAL FISHING METHODS
SAINSBURY
BUSINESS DYNAMICS
Systems Thinking and Modeling for a Complex World
Sterman
McGraw-Hill Irwin
Multivariate Data Analysis
Seventh Edition
PEARSON
Recreational Fisheries
Ecological, Economic and Social Evaluation
Pitcher & Hollingworth
Policy Instruments for Environmental and Natural Resource Management
Sterner
RFF
THE R BOOK
WILEY
Von Brandt's FISH CATCHING Methods of the World
GABRIEL, LANGE, DAHM AND WENDT
Strategic Modelling and Business Dynamics
John Morecroft
feedback systems approach
FISHERIES MANAGEMENT
Progress toward sustainability
McClanahan and Castilla
Multivariate Statistical Methods
THIRD EDITION
Manly
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Higgins
THOMSON BROOKS/COLE
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