The introduction of synthetic fibres in Denmark's fisheries, c. 1945-1970

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Abstract This paper examines the process of technological diffusion based upon an in depth case study of the introduction of synthetic fibres in Denmark's fisheries. The paper shows that this new technology had a particularly long drawn diffusion pattern. The reason for this was the existence of far-reaching institutional barriers. The latter were to some extent underpinned by a rigid State-institutional apparatus. Entrepreneurial initiatives were mainly left to the technology producers and even more so to the fishermen. The State only took any initiative once synthetic fibres proved profitable. This effort, however, soon turned out to be unsuccessful. These results suggest two things. Present day thoughts on regulating the fisheries through technology management might prove impossible due to the decentralized nature of technological change. Furthermore the commonly accepted perception of the State as "the grand entrepreneur" apparently needs readjusting.

Introduction

In the latter part of the twentieth century, the introduction of new technologies – particularly electronics, hydraulics and synthetic fibres – decisively changed the Danish fisheries.[1] Described as a "revolution", its importance was demonstrated through the expansion of catch areas and rapid growth in landings and exports. The success however came at a price. In the mid 1950s, more fish stocks started to show signs of overfishing. This trend continued in the following decades, with quota regulations ultimately being implemented in the 1970s. Quotas quickly became the preferred regulation mechanism. However, the current situation in the fisheries has made it clear that the fisheries policy has not actually resulted in sustainable exploitation of the fish stock. On the contrary, even more fish stocks have become overfished. Recognizing the failure of traditional management, attempts have recently been made to reshape the systems. Hence the need to understand technological development has hardly ever been stronger than now.[2]

This paper seeks to pin down some central elements in technological development and put them into perspective. The paper will investigate the introduction pattern of a new technology. Also some factors affecting the diffusion process will be identified, creating an opening to discuss whether the "grand entrepreneur" can be found in public or private management. This is done by means of an in depth case study of the introduction of synthetic fibres into the

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fisheries. The fact that the introduction of synthetic fibres virtually spanned the whole "revolution" era in the Danish fisheries coupled with the fact that a relatively large amount of information was available from the sources made it an ideal vehicle for such a study.

Many of the problems faced by the fisheries today relates to technology in one way or another. This is particularly true of the resource problem. Technology can be seen as the solution to or the cause of the problems and most would agree that there are no simple solutions. Consequently, this paper will not present ready-made answers, but mainly aims to contribute to the history of the fisheries and more specifically to the discussion about technological developments.

The article is organized as follows. Firstly, it outlines the key features of some theoretical approaches dealing with the diffusion of new technologies, especially focussing on institutions and push/pull factors. It then shifts focus to a micro analytic study of the introduction of synthetic fibres in the fisheries, emphasising the herring and the northern shrimp fisheries. Next, the two separate parts are brought together in order to discuss the findings and put them into perspective. The paper concludes that even though the State played a vital part in bringing synthetic fibres into the fisheries, in the present case the role of the "grand entrepreneur" was actually played by the private entrepreneur. A fact that, in a broader perspective, adds to the discussion on the modern State and its ability to prompt innovation.

Diffusion of New Technologies: Theoretical Approaches

Understanding technological change is no simple task. Historians elaborating on the theme, however, tend to seek their answers in the field of innovation theory. The basis of this paper is also placed in this framework. By way of introduction, it is relevant to discuss the nature of the diffusion process. It is also important to discuss the institutional framework that shapes the process as well as the push-pull factors that add to the overall dynamics.

The successful diffusion of a new technology is decisive for whether the technology will have any economic impact. A number of empirical studies show that in time the diffusion process tends to progress in a way that resembles an S-shaped curve – a so-called cycle of production (see figure 1). To a large extent, these studies started with the works of the economic historian Joseph Schumpeter in the early twentieth century. In his classical "Business Cycles" published in 1939, Schumpeter discerned three different phases in the diffusion process: an introductory phase marked by slow diffusion, which is replaced by a growth phase encompassing rapid diffusion. After several years, the pace gradually slows down and the technology eventually reaches a phase of maturity in which diffusion is stabilized. If, after a while, the mature technology is replaced by a new technology, a new diffusion process will begin and the mature technology will go into decline.[3]

A prevalent explanation for the S-shaped diffusion patterns is that the diffusion of new technologies is limited by the amount of available information on the technologies. Thus the diffusion process is analogue to the process by which epidemics are spread: every user of the new technology passes on information to a non-user, who adopts the use of the new technology and later passes on information. In the introductory phase, most of the population consists of non-users, which means that the spread of information is relatively easy. However, only a few will adopt the use of the new technology since only a limited number of individuals can pass on the information. During the late stage of the diffusion process, more users are able to spread information. Chances of meeting a non-user are few, however, and therefore the rate of diffusion is also low. In between these two stages, the diffusion rate is considerably higher. Most users will meet many non-users and convince them to use the new technology. In this so-called epidemic model, diffusion is mainly a question of the gradual spread of information combined with the advantages of the new technology. Another way to consider the problem is by letting information become commonly known or by letting information be spread from a central source. The S-shaped curves will then occur, as chances are that the technology will follow a normal distribution curve progression.[4] However, these perceptions all have problems. In general, information about a new technology is spread much faster than the use of the technology. Moreover information will seldom be complete or spread gradually, but rather in "packages" of information. The construction of realistic and sterling models is only just starting. However, considering the complexity expected to be contained in such models, it seems to be an open question whether such constructions are possible.[5]

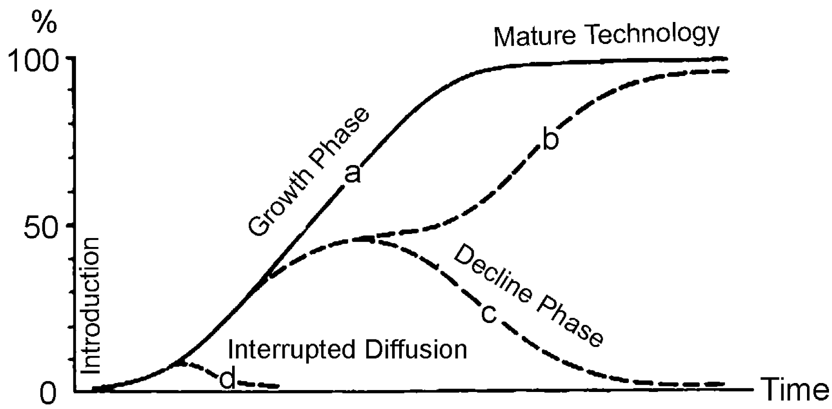


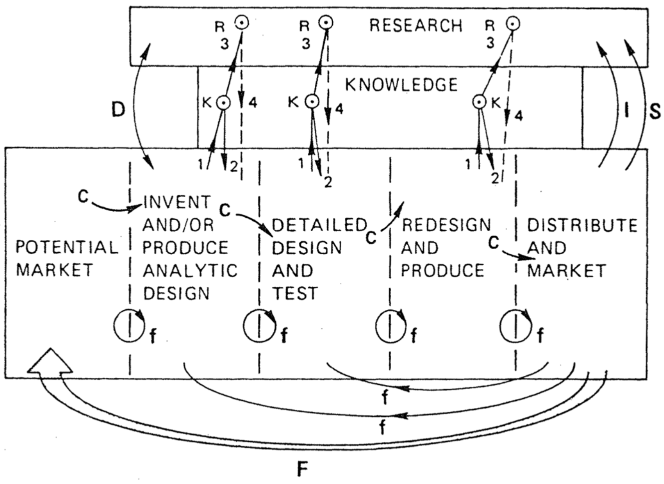
Figure 1. *Schumpeterian, S-shaped, Cycle of Production*
Source: Adapted from Hyldtoft, 1996, p. 25.

As described above, the diffusion can take a number of different turns. Progress can go "awry" to one side or the other, or the diffusion process can be interrupted. In historical investigations, interest has traditionally focussed on the concrete variations in the diffusion process, meaning an encirclement of the factors affecting the strategic choices of the actors. Central questions in this context are: What shapes the diffusion process? Why are some technologies spread faster than others? And why are some technologies not spread at all? To answer these questions, valuable support can be found in the new institutional theorem as interpreted by the economist Douglass C. North. Compared to earlier perceptions of marginal profits as the leading factor in market activities, in the new institutional theorem North studies more qualitative factors.

Fundamental elements are institutions and organizations. According to North, institutions can be perceived as the rules in society or the self-chosen constraints that guide human interaction. It follows that institutions can be both formal and informal, partly in the shape of laws and rules and partly in the shape of conventions and behavioural codices. From time to time rules and codices are broken and punishment needs to be carried out to secure stability. This definition emphasizes two things. Institutions reduce the uncertainty connected with acting in the market by producing a secure and stabile framework and can rectify the human need to develop structured patterns. Like institutions, organizations create a structure for human interaction. The important difference is that organizations are created within the institutional defined framework. The primary goal of the organization is to achieve optimal solutions within these frames. Thus, organizations can have a major influence on which information is spread and where, which in turn means that they become important contributors in breaking down institutional barriers towards new technology.[6]

A relevant question concerning the shaping of the diffusion process is whether dynamics in general are to be found at the producer or the user. Over the years, several models have dealt with this question. Among the first was the so-called linear innovation, in which basic research, often initiated by the State, is seen as the motivator for new technology, because results are forced into production in the form of new technology (push). However, critics quickly responded by saying that if the innovation process is solely based on new technological opportunities and the market has to be created afterwards, there would be considerable uncertainties for success. As an alternative, the innovation process should be seen as being guided by market demands which makes the uncertainty concerning success far less (pull).[7] However, a central problem is a clear-cut identification of the demand concept. Did demands rise before or simultaneously with this innovation and if before, why exactly was it this demand and no other that started innovation?[8] Later research pointed to the fact that the question of push/pull was very dependent on the evolution stage of the technology. The empirical results led to attempts to integrate the two perspectives in a more complex understanding in the so-called chain-linked model (see figure 2).[9]

In the chain-linked model, the notion of a possible market is placed as the first decisive step in the innovation process. However, this does not necessarily have to be initiated directly by market actors. The main point in the chain-linked model is an understanding of innovation and diffusion as processes with continuous feedback between the different phases and between companies and external sources of knowledge. In this process, an ongoing interaction exists between the market and the knowledge sources in the search for solutions to actual problems. As new problems arise, solutions are sought internally and externally. If no solutions are found in the known knowledge source, research will be initiated. Searching outside the known knowledge bases involves greater uncertainty; the search can result in erroneous attempts at changing routines, but also in unexpected solutions – "strokes of genius" – which can potentially create new opportunities or problems.[10] This can redirect the company towards new markets, materials or products, thereby changing the path-dependency. The chain-linked model allows for a more interactive understanding of the complex combinations of the two moving forces – push/pull – in all phases of the innovation and diffusion process.



Chain-linked model showing flow paths of information and cooperation. Symbols on arrows: **C** = central-chain-of-innovation; **f** = feedback loops; **F** = particularly important feedback.

K–R: Links through knowledge to research and return paths. If problem solved at node K, link 3 to R not activated. Return from research (link 4) is problematic—therefore dashed line.

D: Direct link to and from research from problems in invention and design.

I: Support of scientific research by instruments, machines, tools, and procedures of technology.

S: Support of research in sciences underlying product area to gain information directly and by monitoring outside work. The information obtained may apply anywhere along the chain.

Figure 2. *The chain-linked model*
Source: Kline & Rosenberg 1986, p. 290.

The theories above establish the ideal shape of the diffusion process of a new technology, as well as what shapes the process. Furthermore some ideas on the driving forces in the process have been proposed. In the following chapters, these theories will be supplemented empirically, after which further discussions will be carried out and perspective will be added.

The First Introduction of Synthetic Fibres in Denmark's Fisheries

In 1945, the Danish fishermen still used the same materials in their fishing gear as in preceding decades. Vegetable fibres such as hemp, sisal and cotton were used in both nets and trawls. These materials all required meticulous maintenance. The life of the materials strongly depended on how and under what conditions they were used. Thus, materials that were not dried properly or used in areas with relatively warm water with potential rotting in the seabed could not be expected to last for more than a year or two. Even under optimal conditions, the materials rarely lasted for more than five or six years. Consequently, the fishermen were often faced with the substantial expense of renewing fishing gear. Much time and energy was therefore spent searching for preparations which could counteract rot and thereby prolong the life of the fishing gear. Recognizing these problems, in the early 1930s the Directorate of Fisheries had already asked the chemists at the Technological Institute to determine the best ways of conservation under varying conditions. The subsequent research soon produced concrete results. For example, it was proved that the common practice of tarring the nets had no protective effect against rot but simply prevented wear and tear on the fishing gear. During the Second World War, the work of the Technological Institute was reduced to a minimum due to decreased supplies. Much time went into finding alternative materials, with hopes of continuing research into conservation techniques after the war. However, the years immediately after the war continued to be marked by supply problems. There were also new materials in the market that required attention, including synthetic fibres.[11]

The first synthetic fibres in the Danish market were composed of polyamide and marketed under trade names as Nylon, Amilan and Perlon (see appendix table 1). However, within a few years, other synthetic fibres were also introduced, each representing different properties in terms of breaking strength, extensibility and density (see appendix table 2). The first fibres to be used in the fisheries came in the form of monofilaments imported from France, presumably in the autumn of 1945, to be used in troll lining for mackerel. The following year, the new materials were also adopted in the lucrative line fishing for salmon in the Baltic. The first results from these fisheries proved positive. In the leading fishing journals, fishermen expressed their enthusiasm over the benefits of the new product, proclaiming that even though synthetic fibres were more expensive than vegetable fibres, they were far stronger and handier as well as being easier to maintain since they were unaffected by salt water. These persuasive arguments led to more fishermen wanting to use synthetic fibres, which in turn put pressure on the Fisherman's Association to try to influence the relevant authorities to increase imports. Eventually, yearly inputs were more than doubled.[12] In spite of the increased focus on synthetic fibres in the following years, efforts continued to be centred on improving the already known materials. This was partly due to uncertainty about the new technology and partly because synthetic fibres had not yet been developed for all types of fishing. Another factor might also have been scientists at the Technological Institute being unwilling or unable to change focus due to professional pride or lack of suitable machinery. Nevertheless, the private entrepreneurs continued their attempts to produce efficient conservation methods, especially for pound nets. Similar work also continued at the Technological Institute. New results indicated that conserved net materials could be stored for up to six months before their intended use. To the fishermen, this meant that the waterproofing could take place at the time of year that was best suited. Fishermen from all over the country showed considerable interest in the trials. In practice, however, it turned out to be almost impossible for the fishermen to benefit from the results as the materials recommended for mordanting were often difficult to procure. In spite of the limited practical success, the development resulted in a zealous debate on the importance of "knowledge" and "science" on the one side and practical experience on the other side. Several articles dealing with the topic were published in various fishing journals. Even though some conservative opinions surfaced, stating that only practical work could produce results, the keynote was a recommendation of the scientific approach.[13]

The increased confidence in the trials at the Technological Institute meant that the results produced there became increasingly influential. As a result, the fishermen were able to save both time and money, since the numerous independent and often costly experiments were avoided. Still, the trials only concerned vegetable fibres which meant that the fishermen were kept in a similar technological framework and not stimulated to seek new alternatives.

To summarize, the diffusion of synthetic fibres in the immediate post-war years was influenced by several factors. In general the results using synthetic fibres proved positive, causing an increase in demand. Nevertheless prices were still high, which had a moderating effect. Similarly there were limited imports. Furthermore, continued improvements in the existing technology also kept interest in new technology at a low level.

Herring Fisheries

Although the use of synthetic fibres by the end of the 1940s was still restricted to line fishing, and even though several factors moderated the diffusion process, in the early 1950s more indicators suggested a major breakthrough. In the following years increasing amounts of synthetic fibres were imported as more fishing gear was constructed using these fibres.

At this point, the pioneer in the field, the Skaw-based company Iver Christensens Vodbinderi, began experimenting with trawls made from synthetic fibres. The inspiration and ideas for this initiative were mainly adopted from Norway, where experiments with such constructions had been carried out for some time. Initially, the idea was to develop bottom trawls, but it was soon declared that the ultimate goal would be to develop pelagic trawls. In general, expectations concerning the new initiative were high. In the leading national fishing journal it was stressed that similar initiatives in Norway had doubled and even tripled catches compared to ordinary trawls constructed from vegetable fibres. At the same time, it was declared that even though trawls constructed of synthetic fibres were more expensive, the price difference was allegedly not that big. Furthermore the benefit of the new trawls quickly would even out the difference.[14] Optimism ruled, and it was no coincidence that the Skaw became the centre of attention. At the beginning of the 1950s, the Skaw was one of the leading fishing ports in Denmark. Fishermen from all over the country met here and exchanged experiences, especially with Swedish fishermen, but also fishermen from other countries. What created this international and dynamic atmosphere was the extensive autumn fishery for herring. The herring caught in the North Sea, the Skagerak and the Kattegat and landed in the Skaw and other fishing ports in the Northern parts of Jutland supplied the Dutch, Germans and British with herring. The good market conditions naturally gave way for improved earnings, thus creating a surplus profit that could be used to find new innovative paths. However, prices for new technologies such as echo sounders and improved radio equipment were still too high to be borne by the individual fisherman. In this light, the Ministry of Fisheries was urged by the Skaw Fishermen's Association to step in and support the development financially, which the Ministry of Fisheries decided to do in 1950.[15]

Although things appeared to be moving in the right direction, it still took some work before the hopes and optimism could be turned into successful production. A few months after breaking the news that synthetic fibres had been tried in trawl constructions, a small paragraph published in more national fishing journals gave cause for concern. Here it was mentioned that Swedish trails showed that special and rather complicated knots were required to ensure that the meshes retained their intended shape and dimension. The importer behind the Danish trials declared that this had not been a problem in the trials carried out in the Skaw. Any further proof or argumentation was not presented.[16] The lack of such evidence might have left some reservations among the fishermen towards the new technology. Nevertheless, just two months later, it was announced that the first pelagic trawl constructed using synthetic fibres had been sold by the entrepreneurs in the Skaw. The buyer, a local fisherman called Niels Persson, famous for his entrepreneurial attitude, stated that he was going to use the new gear in the herring fisheries and expected to be successful. In certain respects he was proved to be right: the catches did boom, but only after countless adjustments to the trawl. However, the courage to take a new initiative proved essential for the adoption of the "synthetic trawls". In the following months local fishermen all followed his example and ordered trawls, rapidly filling the order book.[17]

While synthetic fibres proved successful in the pelagic trawl fisheries for herring, the benefits of the new technology were also realized elsewhere. At the end of 1951, several fishermen encouraged the net producers to focus on synthetic fibres in pound nets, while declaring that synthetic fibres would become the order of the future. Presumably, with this background, it was not without a certain satisfaction that the company Britagent was able to announce that such nets were on their way to the Danish market. Before the turn of the year, the first nets were sold and by the following year the use of synthetic fibres in pound nets was well established. The preferred choice of material, however, was still vegetable fibres.[18]

Continued Trials and New Materials

The herring fisheries had been an important first step in the introduction of synthetic fibres; however diffusion was still only progressing slowly. As late as the mid 1950s, opinions were still divided on the usability of synthetic fibres. Some experts even claimed that synthetic fibres were not suited for trawls and pound nets. Even in the Ministry of Fisheries, opinions were divided. Ministry officials thus restricted themselves to saying that synthetic fibres had been known for sometime, but that they were still uncertain whether they would be the final solution.[19] Elsewhere, views were less ambiguous. Auctioneer and president of the Fishermen's Association, Niels Bjerregaard, recalled extensive private trials with synthetic fibres in pound nets, proving the superior durability of synthetic fibres. The results led Bjerregaard to believe that even though synthetic fibres were more expensive to acquire, they would prove cheaper to run due to their longer durability.[20]

As a result of the various attitudes and the many private trials, the management at the Technological Institute decided to dedicate more time to trials with synthetic fibres, although compared with the work on vegetable fibres this was still only secondary. It was mentioned, though, that the research field probably would become a main task in the future. For the time being focus was put on finding net constructions with non-skid knots, in the sense that it affected the dimension and shape of the meshes in the trawls. At the same time it was announced that it was of interest to chart the catchability of different forms of fishing gear constructed from synthetic fibres.[21] The state controlled initiative did not stop here. At the end of 1954, it was declared that the state-owned trial vessel "Jens Væver" would be experimenting with different trawl constructions made from synthetic fibres.[22]

By 1957 one of the actual problems troubling staff at the Technological Institute seemed to have been solved; the "knotless nets" imported from Japan theoretically seemed to solve problems with deformations of meshes. This did not gain footing with the Danish Fisheries for several reasons. Firstly the machine parks at the Danish producers were not geared to the production of knotless nets because their main market was the textile industry and not the fisheries. Although some specialised machines for producing knotless nets were bought, they rarely functioned as intended. The lacking investments often meant that the nets produced were of a secondary quality and they proved worthless. As a consequence, the knotless nets mainly gained their footing in pound nets, only becoming successful in other fisheries later on. Knotless nets became a footnote in the following years with the focus on new synthetic materials. By the late 1950s, the staff at the Technological Institute were mostly employed in this line of work.[23]

The intensified focus on the use of synthetic fibres in the fisheries was not only a Danish phenomenon. An international fisheries fair held in Copenhagen in 1959 clearly showed that Japanese, French and German producers were working keenly to come up with new synthetic materials. Of those presented at the fair, most were based on polyamides such as Nylon, Amilan or Perlon. However, materials based on polyethylene were also introduced.[24] At this point polyethylene, which had only just been developed for fishing nets a few years earlier, was almost unknown in Denmark. In countries like France and the Netherlands, however, the material was widely used. One of the first companies to introduce polyethylene on the Danish market was the co-owned company Meyer-Sansboeuf. More or less simultaneously, the Dutch-owned Kunstzijdespinnerij NYMA N.V. also came on the scene marketing polyethylene in the Danish market. Of the two companies, NYMA N.V. especially seemed to thrive. Under the trade name Nymplex, the company successfully marketed their "green wonder nets" to the Danish fishermen. The marketing materials stated that Nymplex was lighter than water, making it well equipped for the construction of pelagic trawls. Furthermore Nymplex was said to be cheaper than other synthetic fibres and less sensitive to low temperatures, making it usable even in frosty weather. Finally, Nymplex nets were said to be superior as they did not need any conservation. According to the retailer, Nymplex nets were the future.[25] Most Danish producers, however, were not of that conviction. Some Danish producers started production, but being unfamiliar with the finer details of shaping the single filaments, the final products ended up being very stiff, making the threads almost impossible to use in trawl constructions. In the practical fisheries, these products also turned out to be problematic as they had a tendency to "curl up" and take up too much storage.[26]

Northern Shrimp Fisheries

For the new polyethylene materials to experience a more substantial breakthrough, more practice and more technological improvements were needed. However, at this point polyethylene materials met with increasing competition from alternative materials such as polypropylene and polyester, in Denmark mainly promoted under trade names as Ulstron and Terylene. These materials were especially well reputed at the leading Danish net producer, N. P. Utzon, which spent a lot of energy and money on marketing. These events all occurred simultaneously with the rise of an extensive fishery for Northern Shrimps in the Fladen Ground area in the North Sea in the early 1960s.

As a consequence, the new materials tended to be put to the test in the Northern Shrimp fisheries. It soon turned out that the new materials did not match the expectations of the shrimp fishermen. Normally, this type of fishery was carried out using only modest engine powers, which was why a fairly large number of fishermen using old small-engined vessels were able to make a living from this fishery. This meant that the fishermen had become used to "fishing hard", pushing the gear to the limit and sometimes even driving the trawl into the bottom without any dramatic consequences as the elasticity of the polyamide in combination with the low horsepower prevented extensive tears in the trawl. This approach, however, was not suited to using the new polypropylene and polyester materials due to their low extensibility. Also during the 1960s, the average size of vessels in the shrimp fisheries grew rapidly, as did the engine power. The muddy seabed of the Fladen Ground area made it easy to get the trawl stock. The mix of "die hard" fishing methods, increased horsepower, inelastic materials and a muddy seabed had an almost predictable effect. Thus, the shrimpers in the Fladen Ground fisheries often watched as their trawl ripped – losing their entire catch – when the trawl got stuck in the bottom. The poor performance of the polypropylene and polyester materials led N. P. Utzon and other producers to rethink their priorities, a process which quickly caused the former reservations regarding polyethylene materials to fade away. Helping this process on its way was also the import of a new type of polyethylene from England. This was rounder and softer in the single filaments, which meant that it was much easier to use in trawl constructions which finally won over more of the Danish net makers.[27]

The pioneering work in the shrimp fisheries meant a breakthrough for polyethylene materials, but generally it also meant that the willingness to experiment with new materials grew substantially. Thus, in the cod fisheries it was learned that the floating ability of the polyethylene materials offered an advantage compared to the polyamides traditionally used. Prior to the introduction of polyethylene, the nets (usually made of Nylon) got soaked and sank, sometimes with good catches weighing down the nets. As the cod fisheries mainly took place on rocky bottom, there was little hope of recovering sunken nets. This disadvantage was eliminated using polyethylene nets.

Polyethylene was also tried out in other types of fisheries. One of these was the small-scale herring fishery conducted by mid-sized trawlers working out of Hvide Sande and Thyborøn on the West coast of Jutland. In this fishery, however, the vessels did not always have enough horsepower to keep the nets at the right fishing depth, due to the floating ability of the trawl and the fairly small trawl doors. Conversely, in this fishery, it was advantageous to use polyester materials. Due to its sinking ability, trawls constructed using polyester remained at the right fishing depth and consisted of sharper filaments compared to the traditional polyamide trawls. This reduced water resistance, allowing for either reductions in fuel consumption or higher speeds when trawling, potentially resulting in higher catches.[28] The rapid development in the 1960s with the introduction of a number of new materials was followed by more modest developments. Only a few really new materials were introduced. At the same time, much energy was invested by the various net producers in finding new net and trawl constructions or new ways to combine the materials. This development marked the end of the introduction and diffusion phase of synthetic fibres into the fisheries.[29]

Perspective: "The Grand Entrepreneur"

The use of synthetic fibres was a long time coming in the Danish fisheries. Getting from the first experimental use to full acceptance of the technology took over twenty-five years. Described in Schumpeterian terms, the process progressed in an almost flat S-shape. The reasons for this are not fully clear, but some major factors can be identified.

Around the time when synthetic fibres first appeared in the Danish fisheries, strong traditions ruled in favour of vegetable fibres like hemp, sisal and cotton, making it virtually impossible for a new technology to penetrate the market. Similarly, a substantial institutional framework underpinned the use of the traditional technologies. The intensive trials conducted at the State-owned Technological Institute made it less likely that the individual fisherman would seek new technological opportunities as the cost of using the known technology continued to be reduced. Despite traditions and institutional barriers, a general sense of optimism marked the first trials with synthetic fibres in the fisheries. However, being privately based and at the same time confined to only two types of fisheries – line fishing for mackerel and salmon – it was deemed to have an limited effect in the general picture. Accordingly the commonly accepted trends within the existing institutional framework did not change. In fact, at this point discussions about the importance of "knowledge" versus "science" turned out to the advantage of the latter, meaning that the known institutional frame, and hence technological paths of development, was reinforced. The moderate success did not stop the private initiatives focussing on synthetic fibres. Thus, experimental work continued, and in time the usability of the fibres was tested in new types of fisheries. This turned out to be vital in the diffusion process. Transferred to pelagic trawls mostly used in the herring fisheries, synthetic fibres proved to be both usable and – even more importantly – profitable. The rapid and positive results in the herring fisheries constituted the first tentative step in making the State institutions interested in the new technology, and in particular the Technological Institute. Also from the early 1950s, the State offered financial support for trials in the herring fisheries. Most funds went into new technological aids – not least echo sounders – being vital for locating shoals of herring. However, a substantial amount also directly or indirectly went into the trials with synthetic fibres. At the time technological problems, synthetic fibres still being a relatively fragile and untested technology might have cooled off State interest or confined it to the single type of fishery at stake. However, having learned about the number of private initiatives being carried out in other types of fisheries, particularly the pond net fishery, and knowing the extent of support to these initiatives from the Fishermen's Association, the State and its institutions decided to follow suit. From the mid 1950s, a number of State-run trials were carried out focussing on synthetic fibres. This allowed a number of new technologies, or more correctly improvements of the existing technology, to be tested under controlled circumstances giving a clear picture of the concrete material usability right from the start. However, the case study could suggest that these trials tended to become too unilateral. If a given material proved suitable in one type of fishing, it was quickly assumed that it would also be usable in similar types of fishing. For example in the early 1960s, in the extensive Northern shrimp fisheries in the Fladen ground, polypropylene and polyester materials which were well suited in other fisheries proved virtually useless as they would tear due to their inelasticity combined with "hard" fishing methods. The poor results however did not change the technological path of the State initiatives. Thus a suitable solution was not found until the shrimpers had carried out a pioneering effort, forcing the majority of the technology producers to seek new technological opportunities. This breakthrough eventually caused the spread of the use of synthetic fibres in all types of fisheries and changed the overall focus to seeking improvements in the construction methods of the net and trawls.

Addressing the question of push or pull in the diffusion process, in the case of synthetic fibres in the fisheries it seems quite clear that the pull factor was rather strong. However, taking the chain-linked model into consideration, more points can be identified in which the interaction between pull and push have been decisive. For example, the State initiative to financially support trials with synthetic fibres in the 1950s meant that many more materials were put on the market than would otherwise have been the case. However, the reluctance or inability to change the innovative path as shown in the case of the northern shrimp fisheries, might suggest that the feedback loops had not been functioning. The reasons for this dysfunction remain unclear but it could be speculated that moderate funding for the Technological Institute and/or focus on more vital development works had an impact. Nevertheless, As a result, the development initiative continued to be in the hands of the fishermen and the technology producers who proved willing or able to respond to demands.

Now, one might ask, what then are the implications of these findings? To answer this question, it might be interesting to bring in modern ideas of reshaping the management systems. The aim of this effort is to change the regulation methods so that instead of regulating "software" (fish), fisheries managers will regulate "hardware" (technology). The general idea is that this reduces the accumulated amount of uncertainty as it is perceived to be easier to control a piece of hardware that you can touch and adjust than illusive pieces of software swimming deep in the sea. While this would be absolutely true, the findings of this paper suggest that controlling technological development is also related to a number of problems. Firstly, in technology areas where strong pull factors govern the development – as in the case of synthetic fibres – managers will need to be in the forefront, cooperating directly with the entrepreneurs, i.e. the fishermen. So far such approaches have been problematic, as fishermen can only be expected to limit their own efforts under certain conditions. Secondly, the impact of technological improvements will only be revealed in time, meaning that regulations will always lag behind. Thus, the findings suggest that even under new managerial systems the power of technological development will remain unleashed. In an even broader perspective, the findings might also imply that the role of the modern State as "the grand entrepreneur" is an over-interpretation of reality. Thus, judging from the case of synthetic fibres, the role of the private entrepreneur should be considered as far more important than hitherto recognized. A statement that extends to other research findings suggesting that modern political desires to prompt commercial success by fostering competence clusters can only have a moderate impact, as ultimately it is the unpredictable – stroke of genius – or entrepreneurial *élan* that drives technological development.[30]

Conclusions

This paper aimed at pinning down some central elements in technological development and putting them into perspective. Focussing on the introduction of synthetic fibres in Denmark's fisheries, it appears that this technology had a particularly long drawn diffusion pattern. More reasons for this have been listed. Among them strong traditions in favour of the existing technologies, difficulties using the same kind of technology (material) in all types of fisheries and most importantly institutional barriers upheld by State-funded institutions neglecting or being unable to change their focus of development.

The failure of State institutions to put sufficient effort into development placed the initiative in the hands of the private entrepreneurs, i.e. technology producers and particularly fishermen. Officials only picked up on the development once privately conducted trial works turned out profitably. Even then, only modest financial support was made available, mainly to cover the heavy expenses related to the trial and error approach of the fishermen. In time, the number of trials carried out by private entrepreneurs coupled with the official support of the Fishermen's Association meant an increasing interest in trials with synthetic fibres on the side of the State. However, this work suffered from a lack of willingness to experiment, perhaps due to reduced funding or more vital tasks requiring attention. Whatever the case, the individual fisherman or technology producer was still left to play the part of the pioneer.

The identification of private initiative as pivotal in technological development makes it tempting to suggest that modern managerial ideas on regulating the technology instead of the fishes will be more than difficult to carry out in reality. Furthermore the findings of the paper could shake the somewhat overplayed interpretation of the modern State as "the grand entrepreneur", as in this case – and others like it – private initiative has proved to have the upper hand.

Notes

1 An earlier version of this paper was read by Søren Byskov, who offered several suggestions for improvements, for which I am thankful. Erika Washburn read drafts of the present version, and I appreciate her comments.

2 For further discussion on this topic and generally on the technological development of the Danish fisheries in the latter part of the twentieth century see Morten Karnøe Søndergaard, *Teknologisk udvikling i dansk fiskeri 1945-2000.* 2004a.

3 Joseph Schumpter, *Business Cycles.* 1939.

4 Paul A. Geroski, *Models of Technological Diffusion.*1999.

5 R. R. Nelson and S. G. Winther, *An Evolutionary Theory of Technological Change.* Pp. 262-263.

6 See: Douglass C. North, *Institutions, institutional change and economic performance.* 1990.

7 Chris Freeman, The economics of technical change, *Cambridge Journal of Economics* 18, 1994. Pp. 463-514; J. Schmookler, Economic Sources of inventive Activity, *Journal of Economic History* 1962. Pp. 1-20.

8 David Mowery and Nathan Rosenberg, The influence of market demand upon innovation: a critical review of some recent empirical studies. *Research Policy* 1979. Pp. 102-153.

9 Stephan J. Kline and Nathan Rosenberg, An overview of innovation, in Landau & Rosenberg (Eds.), *The positive sum strategy. Harnessing technology for economic growth.* 1986.

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11 H. Blegvad (ed.), *Fiskeriet i Danmark.* 1946-48. Pp. 357-365; *Vestjysk Fiskeritidende.* Nr. 21, 1962; Anonymous, *Fiskeriministeriets Forsøgslaboratorium 50 år.* 1981. P. 4.

12 *Dansk Fiskeritidende* 1948. P. 203.

13 *Dansk Fiskeritidende* 1948. P. 196; *Dansk Fiskeritidende* 1948, Pp. 328-329; *Dansk Fiskeritidende* 1948. Pp. 387-388; *Dansk Fiskeritidende* 1948. P. 406; *Dansk Fiskeritidende* 1948. P. 416, *Dansk Fiskeritidende* 1948. P. 428, *Dansk Fiskeritidende* 1949. Pp. 21-22; *Dansk Fiskeritidende* 1949. P. 90.

14 *Dansk Fiskeritidende* 1950. P. 62.

15 *Dansk Fiskeritidende* 1949. P. 3; *Dansk Fiskeritidende* 1949. P. 126-127; Morten Karnøe Søndergaard, *Teknologisk udvikling i dansk fiskeri 1945-2000.* 2004. Pp. 49-50.

16 *Dansk Fiskeritidende* 1950. P. 155; *Dansk Fiskeritidende* 1950. P. 182.

17 Morten Karnøe Søndergaard, *Teknologisk udvikling i dansk fiskeri 1945-2000.* 2004a. P. 156.

18 *Dansk Fiskeritidende* 1951. P. 516; *Dansk Fiskeritidende* 1951. P. 539.

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20 *Dansk Fiskeritidende* 1954. P. 171.

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24 *3. Internationale Fiskeri-Messe. Copenhagen 25/9 – 4/10 1959.* 1959.
25 *Vestjysk Fiskeritidende.* Nr. 14. 1960; *Vestjysk Fiskeritidende.* Nr. 15. 1960.
26 *Fisheries and Maritime Museum, Esbjerg (FOS).* OP 652.
27 *FOS.* OP 652.
28 *FOS.* OP 652.
29 Morten Karnøe Søndergaard, *Teknologisk udvikling i dansk fiskeri 1945-2000.* 2004a. P. 166.
30 Morten Karnøe Søndergaard, S. P. Radio A/S, Aalborg – de historiske rødder til en dansk kompetenceklynge, *Erhvervshistorisk Årbog* 2004b. Pp. 92-115.

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Appendices

Table 1. *Synthetic fibres, raw material and trade names*

Raw material	Trade name	Symbol
Polyamide	Nylon, Amilan, Anzalon, Enkalon, Kapron, Perlon	PA
Polyethylene	Corfiplaste, Courlene, Drylene, Etylon, Kane-light, Nymplex; Polythene	PE
Polyester	Terylene, Dacron, Diolon, Tergal, Terital, Terlenka, Tetoron, Trevira	PES
Polypropylene	Meraklon, Courlene PY, Danaflex, Hostalen P., Nufil, Polypro, Pylen, Spunstron, Trofil, Ulstron	PP
Polyvinyl alcohol	Cremona, Kuralon, Kuremona, Manryo, Mevlon, Vinylon	PVAA
Polyvinyl chloride	Envilon, Rhovyl, Teviron, Vinyon E	PVC

Source: Gerhard Klust, Fibre ropes for fishing gear, Surrey 1983, pp. 16-21.

Table 2. *Synthetic fibres, properties*

	PA	PE	PES	PP
Breaking strength	High	Average	High	High
Extensibility	High	Average	Low	Low
Density	Sinks	Floats	Sinks	Floats
Shrinking in water	Average	None	None	None
Price	Average	Low	High	Average

Source: Ulrik Jes Hansen, Fiskeri med trawl, Hirtshals 1986, p. 19.