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The economics of technological innovations to mitigate ecosystem effects of fishing: The pulse trawl in the North Sea

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SUMMARY

In this study we focused on the mitigation of the benthic impacts of the beam trawl fisheries for sole through the use of electricity as a technological innovation (pulse trawls replacing traditional beam trawl) and particularly on the economics of the gear transition. We identify drivers that probably influenced the technological change and got insight in the factors that may promote or hamper the use pulse trawl. The studies show that the pulse trawl is economically more profitable than the traditional beam trawl when targeting sole. This is particularly true when fuel prices are high and also when the landing obligation is implemented (because the catch is more selective). In the Dutch fishery, the wages of the crew operating with pulse are also higher which probably explain the support that the pulse trawl received from the crew. However this is not the case in the Belgian fleet where crew wages are based on value of landings only (as opposed to value of landings minus fuel price in the Dutch fishery). In addition to the good economic performances of the pulse trawl, non-economic factors have played a role in the uptake of the pulse trawl in the sole fishery. In particular, the information sharing amongst fisher through study groups and demonstration days have accelerated the process in the Netherlands. The support of the Dutch government was also influential. In contrast, barriers such as limiting days at sea in the North Sea for Belgian fishers and the controversial image of the pulse in Belgium may have hindered the adoption of pulse in Belgium.

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INTRODUCTION

Bottom trawl fisheries operate over large parts of the continental shelfs. A recent study revealed that in European waters the footprint ranged between 53-99% per habitat type down to 200m depth (Eigaard et al., 2017). Since bottom trawls are generally not very selective, substantial amounts of undersized or unwanted fish and benthic invertebrates are caught and discarded (Alverson et al., 1994). Bottom trawling may crush benthic organisms, or damage biogenic structures, imposing an additional source of mortality to benthic invertebrates (Collie et al., 2000; Kaiser et al., 2006). In particular gears that penetrate into the sediment, such as dredges and beam trawls have raised concern with regard to the impact on the benthic ecosystem (Jennings and Kaiser, 1998; Polet and Depestele, 2010; Eigaard et al., 2016).

Studies to replace the mechanical stimulation by electrical stimulation to chase flatfish out of the seabed have already started soon after the introduction of the double beam trawls in the early 1960s (review in (Soetaert et al., 2015). In the initial stages, the research was publically funded but since the 1970s a private company became interested and invested in the development of a prototype. By the mid-1980s, a promising prototype was available but the threatened state of the sole stock and the large overcapacity in the fleet made the European Union decide to add electric or "pulse" fishing on the list of illegal fishing methods. The private company continued working on improvements of the technique and produced a commercial prototype in the 2000s. By that time the beam trawl fisheries became unprofitable because of the increased fuel cost and the low quota. The Dutch government saw the pulse trawl as a viable alternative to the beam trawl. In the pulse fishery, the heavy tickler chains or chain mats are replaced by lightweight electrodes. This alternative stimulation is based on producing a low energetic electric pulse field at the seabed that induces a cramp reaction in flatfish (Verschueren et al. 2014). If applied correctly, there is less intense seafloor contact and hence less disturbance of the benthic ecosystem and lower fuel usage. Preliminary studies showed high economic potential and could reduce the adverse ecosystem effects in particular in terms of the bycatch of undersized fish and benthic invertebrates (Renders et al., 2011, Soetaert et al., 2015, van Marlen et al., 2014). The Dutch government supported a year round test of the commercial prototype (van Stralen, 2005) and provided subsidies for the investment in the gear for five other vessels (Haasnoot et al., 2016). Since the successful trials, pulse trawling gained momentum in the Netherlands and the number of temporary licences was increased stepwise from 5 in 2010 to 84 in 2014. The increase in pulse licenses raised fierce criticism from fisheries, NGO's and other North Sea countries. The Dutch government has commissioned various research projects to address the concerns raised in the public debate that will be the basis for an evaluation of the method in 2019.

In this study we looked at the socio-economic aspects of the transition to pulse trawl in the North Sea sole fishery. To understand the dynamics of the uptake of technological innovation in the fishery we compared two fleets within the fishery, a Dutch and a Belgian one. The pulse technique is widely used in the Netherlands but has not been adopted in Belgium. We were therefore interested in understanding what differences between the two fleets could explain the difference in investment behaviour. In the literature, investment decisions in fisheries are mainly driven by a profit maximising behaviour (van Putten et al. 2012). However most available models are theoretical, the lack of good data on investment precluding empirical analysis. In their review, Nøstbakken et al. (2011), have identified gaps in knowledge on investment behaviour. Quantitatively, the lack of time-series data limits the possibility to run econometric analysis. In addition, more qualitative drivers are also often ignored. In this study we combined quantitative and qualitative analyses in order to identify drivers from four broad categories: economic, regulatory, social and governance.

1 MATERIAL AND METHODS

1.1 Data

To assess the economic performances of the innovative gears, we used detailed economic information collected by the Netherlands and Belgium in the context of the Data Collection Framework (DCF; EC 2008). Economic data on fishing vessels within the Netherlands are collected by Wageningen Economic Research. The data contain detailed costs and earnings data at the fishing trip level for a subset of the fleet (*panel data*) and landings and effort data per trip for the whole fleet. Belgian data are collected by the Sea Fisheries Authorities (Flemish government, department of agriculture and fisheries) and contain annual economic data (costs and earnings) for most of the vessels (response rate of about 90% of the active Belgian fleet) and landings, effort and value of landings at the trip level.

The Dutch North Sea flatfish fishery has been transitioning to pulse trawl since the late 2000's and by 2012 hardly any traditional beam trawlers were left in the Dutch panel data. To allow for the comparison between the traditional beam trawl and the pulse trawl, the landings composition, fuel consumption and costs per unit of effort per metier were taken as an average of 2010-2012 data. The number of vessel, effort and fish and fuel prices were used as of 2012.

1.2 Fleet description

In this study we focus on the transition from traditional beam trawl to pulse trawl in the North Sea flatfish fishery, and more specifically, in the fishery targeting sole. We therefore selected the Dutch and Belgian fleets the most active in the fishery, following the fleet segmentation used in the EU data collection framework. The Dutch TBB_40XX fleet and the Belgian TBB_2440 fleet landing 70% and 45% of the respective national North Sea sole landings were selected.

In 2012 the Dutch fleet consisted of 60 vessels larger than 40m mainly using beam trawls (or a related variant). This fleet is important for the Netherlands, in 2012, it represented 40% of the total Dutch effort (in kWdays) and 23% of employment in the Dutch fisheries (data, STECF, 2016). In terms of landings, the contribution of the fleet to the total Dutch landings is 11% in volume and 31% in value. The fleet mainly operates in the North Sea and targets flatfish with pulse trawls, traditional beam trawls and beam trawls with a sumwing with mesh sizes between 70 and 99 mm (Figure 1). Since 2009, the effort of the fleet has rapidly switched from traditional beamtrawl (TBB) to pulse (PUL) and sumwing (SUM). Sole and plaice are the main target species for the fleet (around 80% of the landings). Plaice represents about 60% of the landings in volume, but only accounts for 26% of the total value of landings. In contrast, sole only represents 19% of the volume but 54% of the value of landings.

The Belgian fleet, 31 beam trawlers of a length between 24 and 40 m using mesh sizes between 70 and 99 mm, represented 38% of the total active Belgian fleet in 2012, accounting for 69% of the weight and value of landings and 48% of employment (data, STECF, 2016). They target sole in the North Sea with a mix of traditional beam trawl and sumwing and they also fish for sole in the English Channel and the North Atlantic with beam trawls (Figure 1). Plaice represents 29% of their landings in volume, while only 12% of its value. Sole represents 13% of the volume, but 43% of the value (data, STECF, 2016).

A hypothetical "pulse trawl" activity was introduced in the selected Belgian fleet based on data from Dutch vessels of over 40m. Multiplying factors of fuel consumption, gear costs and landing composition were calculated for traditional beam trawls/pulse and sumwing/pulse trawl. In 2012, after a few years of investment in sumwing encouraged by subsidies granted by the Flemish government, about 50% of the fleet operated with sumwing. Because the Belgian economic data could not be separated between traditional beam trawl and sumwing, the multiplying factors were weighted to reflect the presence of sumwing in the Belgian fleet.

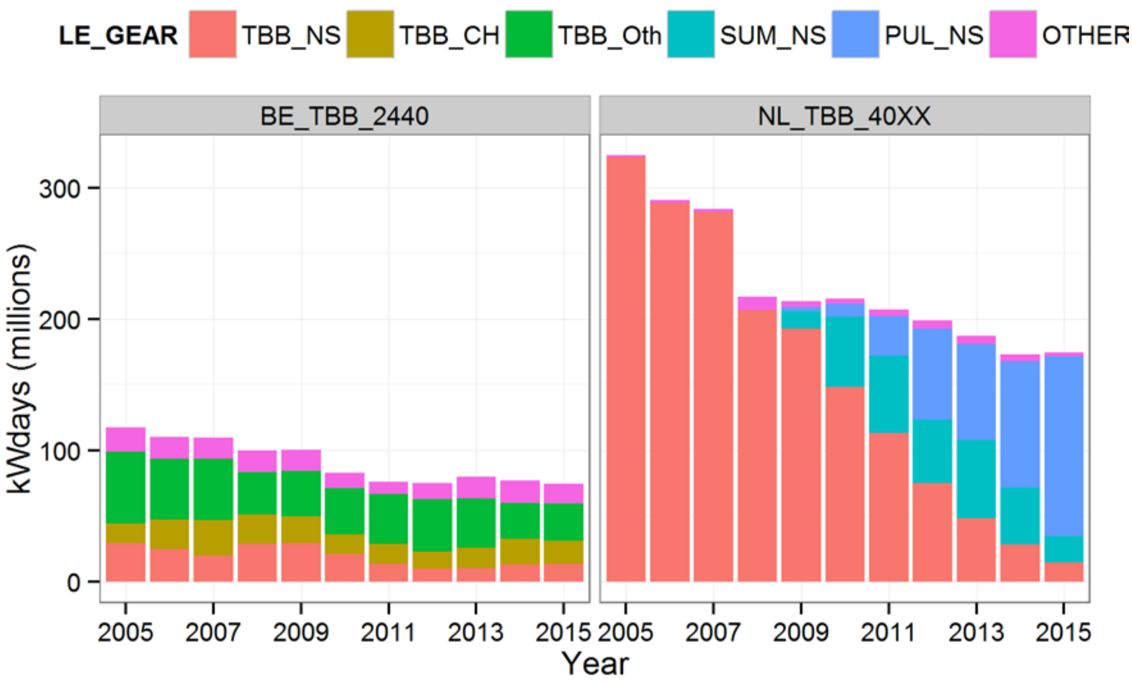

Figure 1 Effort in kWdays for the different metiers for 2005-2015 period for the two fleets of interest. Metiers are defined by the gear and the area fished (NS;North Sea, CH: English Channel, Oth: North Atlantic)

1.3 Economic analysis

The data was used as an input for the Senseco model (Merzéreaud et al. 2014, Deliverable 5.2, Benthis project). The model allows very simple economic analysis based on effort, catch composition per metier, prices and variable and fixed costs. To compare the relative profitability of different metiers *m* for the fleet *f*, the short-term profitability $\pi_{f,m}^{shortterm}$ per day at sea is calculated as the difference between the value of landings and the operating costs.

$$\pi_{f,m}^{shortterm} = \sum_{s} VPUE_{f,m,s} - (fuelC_{f,m} + oilC_{f,m} + crewC_{f,m} + landC_{f,m} + foodC_{f,m} + iceC_{f,m})$$

Where $VPUE_{f,m,s}$ is the value of landings per day for the fleet *f*, metier *m* and species *s*. The operating costs per day in metier *m* include fuel costs $fuelC_{f,m}$, oil costs $oilC_{f,m}$, crew costs $crewC_{f,m}$, landing costs $landC_{f,m}$, food costs $foodC_{f,m}$ and ice costs $iceC_{f,m}$. The crew costs $crewC_{f,m}$ depend on the remuneration calculation which can be very different between countries. In Belgium and in the Netherlands, the crew salaries are calculated as a share of what is called the “rest-to-be-shared” (RTBS) and which is often the value of landings minus some operating costs. Furthermore, in Belgium, if the calculated salaries fall below a minimum salary, the difference is compensated. Because the calculated wages were above the minimum salary, we didn’t include the minimum wage in our calculation.

$$crewC_{f,m} = RTBS_{f,m} \cdot cshr_{f}$$

Where $RTBS_{f,m}$ is the theoretical RTBS per unit of effort per metier. For the Belgian fleet it corresponds to the value of landings whereas for the Dutch fleet it corresponds to the value of landings minus the fuel costs. $cshr_f$ is the crew share i.e. the percentage of the rest to be shared used as wages. For the selected fleets, the crew shares for the whole crew (including skipper) are 29.5% for the Belgian and 33.2% for the Dutch.

A number of assumptions and choices were made to generate the needed data. The average number of days at sea for each metier was calculated as an average for the fleet, that is, it was assumed that all vessels used all the metiers. The model required a number of variables by metier and fishing effort. However, for Belgium not all variables were available at a metier level as this is not required under the DCF and only available yearly on a vessel level costs were therefore allocated equally across metiers, for example fuel cost, food cost, oil cost and ice cost per day were the same for all metiers.

To assess the economic incentive to invest in pulse trawl, the return on investment of using pulse trawl in the North Sea sole fishery instead of beam trawl is calculated for different scenarios (see below). For each of the scenarios, we calculated two variants, one with the 2012 effort distribution (called *"TBB"*) $E_{f,m}^{TBB}$ and one in which the effort in the North Sea sole fishery is allocated to pulse (*"PUL"*) $E_{f,m}^{PUL}$. The return of investment is computed as the ratio of the difference between the annual profit using pulse trawl and the annual profit using the 2012 metier distribution and the investment cost $invest$. The investment cost includes the cost of the pulse trawl and its installation on a vessel and the estimated price is the average price collected in the Dutch fishery (350.000 euro, see Turenhout *et al.* 2016).

$$ROI_f = \frac{\left(\sum_m \pi_{f,m}^{shortterm} \cdot E_{f,m}^{PUL} - \sum_m \pi_{f,m}^{shortterm} \cdot E_{f,m}^{TBB}\right)}{invest}$$ [1]

The annual profits are estimated as the short term annual profits computed as the sum of products of the short term profit per day at sea for each metier and the annual effort in the metiers. Fixed costs are ignored because they are not assumed to change when changing gears.

1.4 Scenario description

The first reason mentioned to switch to pulse trawl is often the fuel price. The fuel price varied greatly in the past years (Figure 2). To assess how the fuel price volatility impacts the economics of the fleets, we run three different fuel price scenarios:

- base fuel price was 0.66 euro/l.
- low fuel price (0.58 euro/l)
- high fuel price (0.80 euro/l)

[1] In this calculation of the return on investment, depreciation and interest costs as well as possible extra quota costs have been disregarded because of a lack of data.

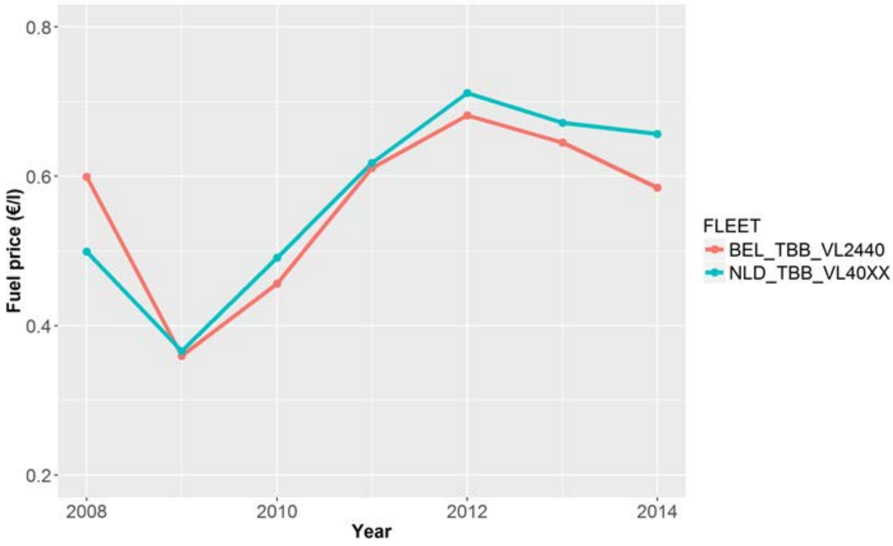

Figure 2 Fuel prices between 2008-2014 for the Belgian beam trawler fleet with a length of 24-40m and for the Dutch beam trawler fleet with a length over 40 m (Data source: STECF 2016).

1.5 Interviews

During a period of two years (2015-2016) qualitative interviews were held with fishers, policy makers, NGOs, and researchers. This data was completed with information from documents, reports, and newspapers, which were analysed on its content.

The interviews gave insight into why fishers had transitioned to pulse. Both pulse trawl users and fishers who decided to keep fishing with the traditional gear or to invest in another technological innovation (such as sumwing) were interviewed. The different drivers of investment identified have been sorted in the following categories:

- Economic drivers, the fishery must remain economically viable with the technological innovations. The robustness of the economic viability to changes of fuel prices have also been deemed important, as was the access to funding.
- Regulatory drivers, e.g. quotas (change in fishing gears impact the catch composition and fishers must make sure that they have quota to cover their landings), effort (in the case of pulse, the utilisation is currently limited to the North Sea while the Belgian fleet is also very active in the English Channel and the Bay of Biscay).
- Social drivers, the fishing crew of vessels are paid based on shares of the value of landings minus some costs. By changing the catch composition, innovative gears also change the value of landings and impact crew salaries. The crew can also influence the investment decision of the vessel owner if they accept or not to use specific gears. In addition, the social network and information sharing around technological innovation is important in the level of uptake of new technology.
- Governance drivers, the Dutch government influenced the process by funding of research and delivering temporary permits to companies.

2 RESULTS

2.1 Economic drivers

2.1.1 Profitability

In the North Sea, the pulse metier (PUL_NS) is the most profitable to target sole in the North Sea for both fleets. In the Dutch fishery, the pulse metier (PUL_NS) is about twice as profitable as beam trawl (TBB_NS) and sumwing (SUM_NS). In the Belgian fishery, the pulse metier is 1.6 times more profitable than beam trawl. The most profitable metier is the beam trawl metier outside the North Sea (TBB_Oth).

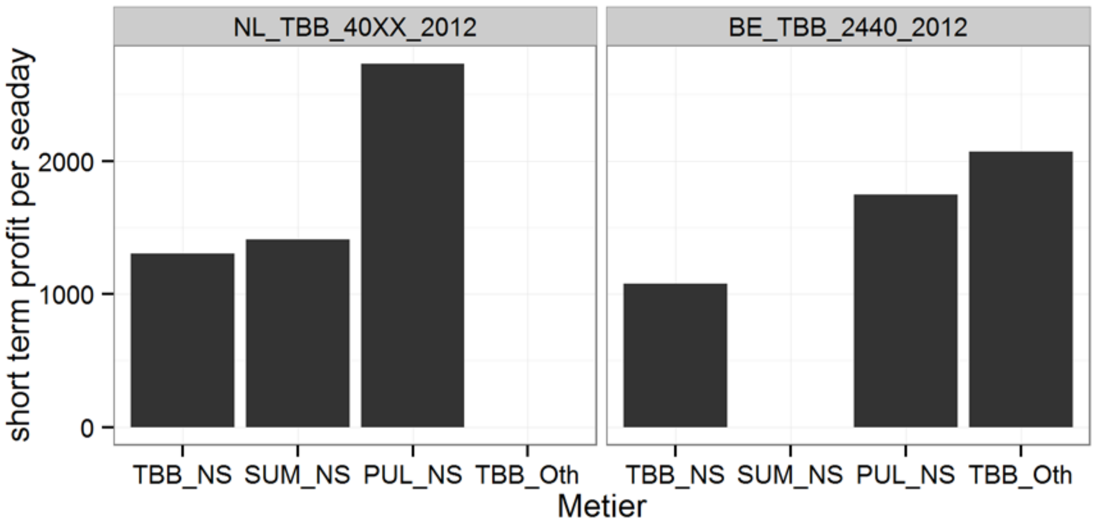

Figure 3 Theoretical short-term profitability of the Dutch and Belgian beam trawl fleets per seaday in the different metiers

The return on investment for the pulse trawl lies at 24.4% for the Dutch fleet way above the long term interest rates for the Netherlands in 2012 (3%, OECD, 2016) and 6 % for the Belgium fleet slightly above the 4.2% long-term interest rate.

2.1.2 Change in fuel price

For many pulse fishers that switched in 2010/2011 it was important that a new technique lowered the fuel costs, as these costs had been increasing enormously, making the fishery non profitable. The first results of the pulse trawlers were financially positive. These results were shared on many occasions leading to a change in the attitude of the fishers (Haasnoot, 2016). In addition, a catch comparison was done between two pulse trawl vessels, and a traditional beam trawl. Results showed a positive performance of the pulse compared to the beam trawl in terms of fuel consumption, costs, and catches (ibid).

Unsurprisingly, the fuel price has a great impact on the short term profitability of metiers (Figure 4). However the impact of changing fuel price is greater for beam-trawl and sumwing metiers than for pulse. For both fleets, an increase from 58cts/L to 80cts/L leads to a reduction of the profitability of the pulse metier of around 20% whereas the profitability of the beam trawl metier decreases by around 65%. In the Belgian case, high fuel prices make the pulse metier as financially attractive as beam trawl in other areas.

Investing in the pulse technique becomes increasingly interesting as the price of fuel increases (Figure 5), return on investment reaches 30% for the Dutch fleet and 8% for the Belgian fleet with the higher fuel prices.

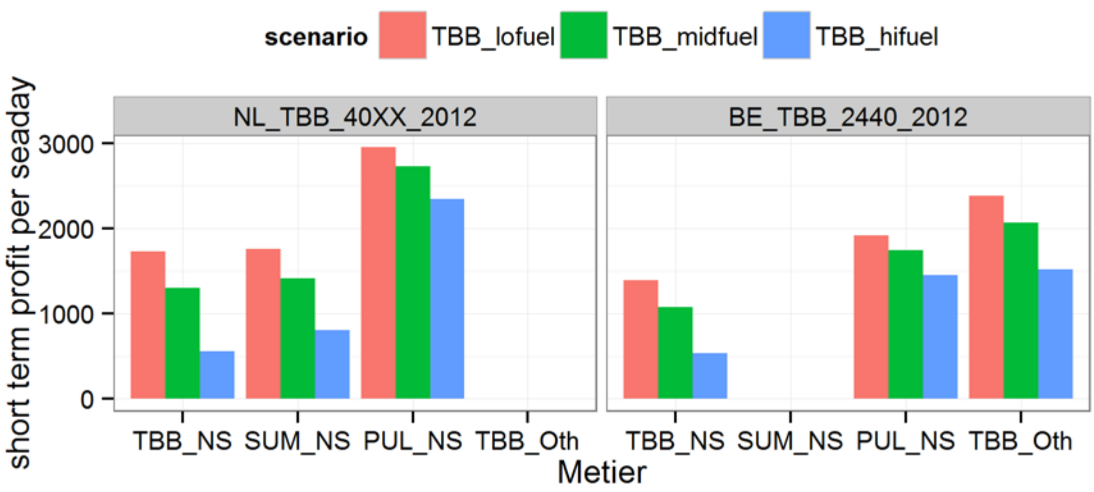

Figure 4 short-term proftitability per seaday in the different metiers of the two fleets for low, medium, and high fuel prices

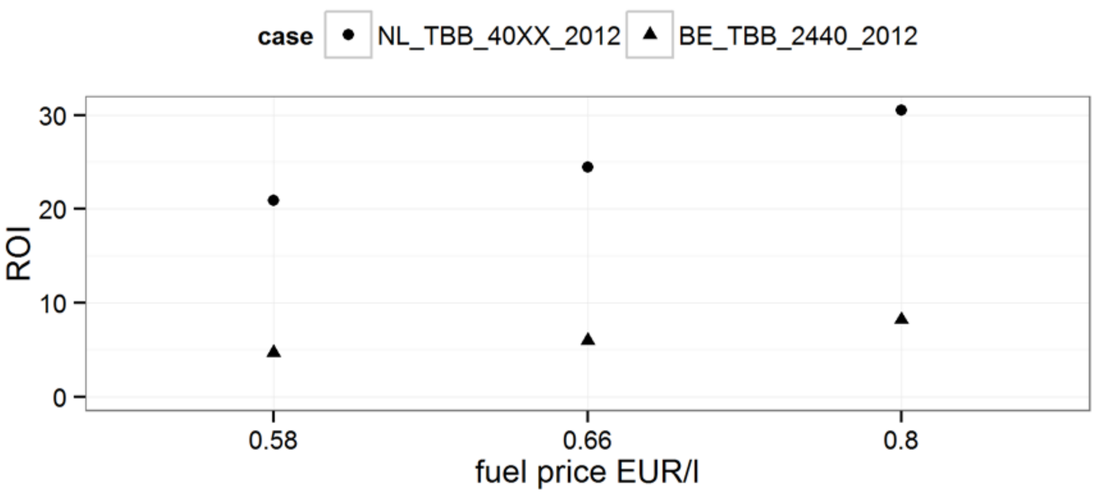

Figure 5 Return on investment in the pulse trawl (%) for both fleets for different fuel prices

2.1.3 Access to funding

In order to switch to the pulse technique fishers needed to have access to finance, either through the bank, with help from the government, or with private capital. Some fishers have received a (regional) subsidy to stimulate them to switch to the pulse, but most fishers had to request the bank for a loan. It was clear that the banks wanted to stimulate the fishers towards sustainability. In 2011 a 'Think Tank' of the ING published a report in which they stated that from then onwards they would only invest in fishing techniques that are not damaging the environment (Visserijnieuws, 2011).
"The bank pushed us, because in their opinion we were not innovative enough. That is how it all started in 2010." (personal interview with fisherman, 2015).

2.2 Regulatory drivers - Quota limitation

In order to switch to pulse one had to have access to sole quota. This access was secured either through ownership or through renting sole quota. The rental prices for sole quota have increased dramatically since 2014 after the second set of 42 pulse permits were made available (Figure 6). The increase in demand led to a fourfold increase of the rental price between 2013 and 2014. Although the TAC decreased between 2013 and 2014, it is not enough to explain the increase in demand as such changes in TAC were already observed in 2007 and 2008 without significantly affecting the quota lease price. The specialisation of the pulse fishers for sole mainly drove the changes on the quota lease market.

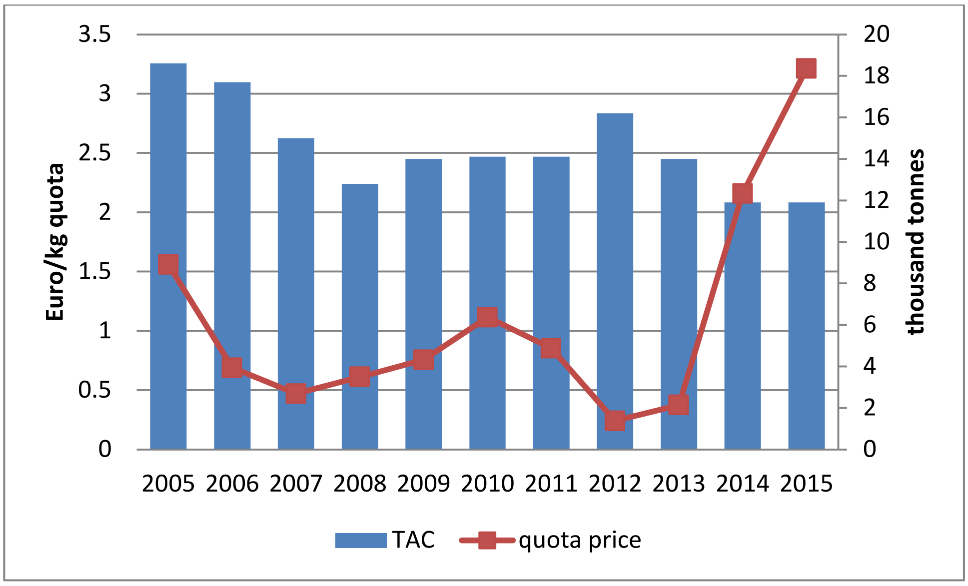

Figure 6 lease price of quota of sole in the Dutch fishery 2005-2015 (source: Wageningen Economic Research) and TAC for sole in the North Sea (source: ICES)

2.3 Social drivers

2.3.1 Change in crew salary

The average crew wage (including skipper) showed differences according to the operated metier. For the Dutch fleet the metier with the highest daily wage was the pulse metier, whereas pulse delivered the lowest wage in the Belgian fleet (Figure 7). Given how the wages are calculated in the two fleets (as a share of income minus fuel cost for the Dutch and just income for the Belgian), fuel price only had an impact on Dutch wages. Not only did the pulse metier have the highest wages, it also had smaller wage variability when fuel prices changed compared to the other metiers.

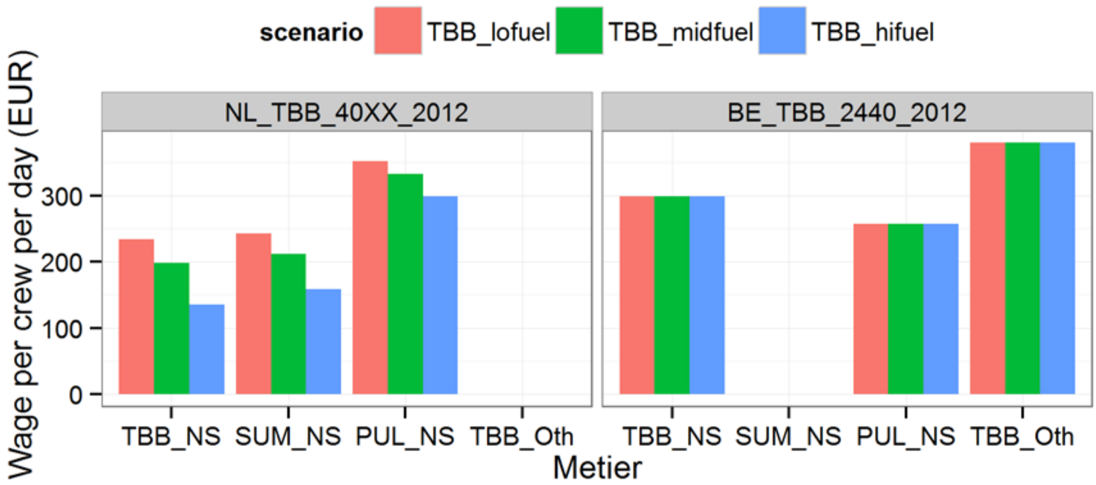

Figure 7 average daily wage per crew per day per metier for different fuel prices

2.3.2 Role of crew

The crew played a role in the further uptake of pulse. Some crew members left their company to start working for owners that had already switched to the pulse technique. They did this because they foresaw to gain a higher salary at pulse vessels than at vessels that still applied the traditional beam trawl. As good crew members are rare, this development provided an incentive for owners to switch as well.

2.3.3 Role of social network

Besides economic factors, fishers are, in their decisions, highly influenced by the behaviour of their peers, but also by their own norms and values. In this section we refers to these factors as social factors.

The transition to the pulse trawl is highly influenced by a couple of fishers that took the lead in this process, stimulated by the government. In 2005 a regular fishing vessel (UK153) started testing the gear for the first time in practice. Before that research institute IMARES had been developing the gear with subsidy from the government. In 2008, the Ministry set up Study Groups with the aim to stimulate innovative fishers to work together in small groups towards innovation and sustainability. Of the 14 groups in total, one group focussed on further uptake and development of the pulse fisheries, and another group focussed on the twinrig technique. The fishers from the Study Group pulse were the first ones (after the UK153) who installed the technique on board. The group of pioneers (i.e. UK153, and Study Group fishers) played an important role in the further uptake of the pulse in the Netherlands. Fishers learned about the technique through their peers, through demonstration days, experienced relatives, and local communities. The community of Texel is an example of a community that played an important role in the information exchange. According to interviewed fishers who switched to pulse, the fishers in Texel were very open, and willing to show them how everything worked. This helped other fishers in their decision.

2.4 Governance drivers

Finally, the switch to the pulse technique was influenced by several aspects that can be grouped under the term governance. The development of the gear was highly stimulated (top down) by the government through subsidies, but also through the release of permits. In the pulse fishery, fish are caught by means of light electric pulses that cause muscle contractions in fish, resulting in them being released from the sea bottom and caught in the net (Quirijns et al, 2013). As electric fishing is not permitted in Europe a derogation is required. In the Netherlands there were three rounds of derogation in which a certain number of permits was released (84 in total). By pushing for the permits in Brussels, the Dutch Ministry gave a clear sign of support for the pulse technique.

In addition two important institutional arrangements were set up by the Ministry to push innovation, and sustainability in the fisheries sector further (more bottom up). These arrangements were: 1) The Fisheries Innovation Platform (VIP), which was set up in 2006 with the aim to stimulate the debate on fisheries, as well as investments in sustainable initiatives, and 2) The already mentioned Study Groups. Innovative fishermen were invited to participate in the VIP and the Study Groups. This resulted in more contact and collaboration among fishers from different regions (de Vos and Mol, 2010), as well as more collaboration between innovative fishers and the government. Knowledge, and information regarding opportunities for permits as well as subsidies were exchanged:
"I was a member of the VIP feedback group. There I met one of the fishermen who participated in the Study groups. We got in closer contact. As a member of the feedback group I also talked to many other fishermen and to the Ministry. There we heard about the permit, and we decided to go for it." (personal interview with fisherman, 2015).

With additional subsidies, research, and networking the uptake of the pulse fishing gear became a fact. Once the development of the gear had reached a level that made it attractive for fishers to invest in the gear.

3 DISCUSSION

3.1 Economic

Fuel costs represent the largest operating costs at the trip level for towing gears. Changes in fishers behaviour in relation to fuel prices have already been observed in the North Sea flatfish fishery where fishers have reduced their steaming and fishing speed to save on fuel consumption (Poos et al. 2013). However, speed can only be reduced until a certain limit before affecting the catchability of the gear. For a longer term solution, Dutch sole fishers have transitioned to innovative fishing gears that are lighter and less contact with the bottom. Pulse trawl is the most novel gear that has been introduced in the North Sea sole fishery in the past 10 years and it reduces fuel consumption greatly, increasing the economic profitability of the Dutch fishing fleet. If used in the Belgian North Sea sole fishery, it would also improve the economic performance of the Belgian fleet, although to a lesser extent. Indeed, the Belgian vessels have been limited in the amount of days at sea and sole quota they are allowed to fish in the North Sea (where pulse is allowed) and the eastern Channel (where pulse is currently forbidden). Because days at sea and quota are allocated individually to each vessel without possibility to exchange between vessels, if a vessel were to invest in the pulse technique, they would only be allowed to fish with the gear for a maximum of 150 days a year. The economic benefits of the pulse technique are particularly strong when fuel prices are high. Investing in pulse in case of fuel price around 80cts/L is beneficial for both fleets and for the Dutch fleet well above long term interest rates, meaning that it is a better investment than in relatively low risk stocks.

Access to funding through bank loans was facilitated by the availability of subsidies to invest in pulse and by the research results around the use of pulse which rapidly demonstrated its economic performances and convinced fishers and banks it was more sustainable than the current practices.

3.2 Regulatory

The availability of sole quota in the Dutch fishery has been an issue since the number of permits was double to 84 permits in 2014. While the traditional beam-trawl was equally adapted to target sole and plaice, the pulse trawl is more efficient to catch sole but not really suitable for plaice. The increased demand for individually allocated quota of sole combined with relative low TAC has driven the lease price of sole quota up. This is a barrier to investment because to be able to go fishing with pulse fishers will first have to secure sole quota, adding to the initial investment.

In Belgian, quota and effort rights are also allocated individually but are not tradable. So unfortunately, fishers could not decide to focus on the North Sea (the only area where pulse trawl is currently allowed) part of their activity by trading their Channel, Bay of Biscay and North Atlantic quota for sole quota in the North Sea. This means that fishers who were to invest in pulse trawl could only partially benefit from their new gear as they would have to change gear again to go fishing in the other areas. No doubt that the diagnosis for the Belgian fleet would change if the pulse trawl was al allowed in the English Channel.

In the context of the current Common Fisheries Policy, the pulse trawl has also additional advantages. A theoretical analysis (Batsleer et al. 2016) and a pilot study (Buisman and Turenhout, 2016), indicate that the reduction of unwanted catch in the pulse fishery compared to the traditional beam trawl fishery would mean that the extra costs caused by the landing obligation are much lower for a pulse trawler than for a beam trawler.

3.3 Social

Wages in the Dutch pulse trawl fishery were higher than in the beam trawl fishery. The opposite was however expected in the Belgian fishery due to the way wages are calculated in both fisheries. Higher or lower wages would strongly impact the level of support of the crew of the new gear. While Dutch crew have been moving to pulse vessels to benefit from the higher wages, no support has been seen in the Belgian fleet.

Beyond the crew onboard vessels, the social links in the Dutch fishing industry and with the researchers have been key for the development and the adoption of the technique. Information sharing and particularly demonstration days were key to improving the acceptation by the community. The pulse trawl benefited from a strong group of pioneers who led the development of the gear.

3.4 Governance

The government support was extremely influential in both the development and the adoption of the pulse technique in the Dutch fishery. The government funded the platform where research could be done, information shared and gears tested. In addition, they subsidised some of the early adopters who contributed to convincing the other fishers that the practice was both economically viable and practically workable. The Dutch government also pushed at the EU level to obtain derogations for a gear that is still illegal in most EU waters.

CONCLUSION

A combination of good economic performances, increasing fuel prices, improved crew remuneration, strong governmental support, encouraging scientific evidence on catch composition led to the rapid adoption of the pulse trawl in the Dutch fishery. The case remain more nuanced in the Belgian fleet. In Table 1 we synthesised the information available about the drivers of adoption identified in the two fleets.

While it remains unclear which factors have been decisive in the uptake of the pulse trawl in the Dutch fishery, it is obvious from the table that the Dutch situation was much more favourable for the development of the technique. However, even in the Netherlands, differences can be observed between fisheries. The shrimp fishery has also been experimenting with electric fishing but the governmental support has been milder than for the sole fishery and to this day only a few vessels are now operating with pulse in the shrimp fishery.

Table 1 Synthesis of the drivers expected to impact the investment decision in the pulse technique in The Netherlands and Belgium. Signs represent the impact of the driver on investment decision in each fleet. (+) means a positive impact, (-) means negative impact and (=) means no impact. Question marks (?)indicate cases with unknown effect

Drivers	**Modality**	**Netherlands**	**Belgium**
Economic	Profitability of pulse	+ pulse trawl profitability is higher than the profitability of traditional beam trawl or sumwing in the North Sea	+ pulse trawl profitability is higher than the profitability of traditional beam trawl or sumwing in the North Sea. However the North Sea activity of the vessels of the fleet only represent a small fraction of the total effort
	ROI	+ well above long term interest rates	= slightly above long term interest rates
	Access to funds	+ Pushed by banks and subsidies	?
Regulatory	Quota	- Sole quota has been limiting since the second set of permits were granted, increasing the lease prices	- pulse is only allowed in the North Sea where sole quota is only a small part of the Belgian quota for sole (also in the Channel and Bay of Biscay) and vessels cannot trade quota to focus on one area.
	Effort	= effort in the Southern North Sea where sole is caught hasn't be limited	- as quota, effort in the North Sea is limited at the individual vessel level, with no possibility to concentrate rights
	Landing obligation	+ selectivity of pulse trawls is improved compared to the traditional beam trawl and less small fish and benthos are brought onboard	+ selectivity of pulse trawls is improved compared to the traditional beam trawl and less small fish and benthos are brought onboard
Social	Wages	+ higher wages and less variation with fuel price changes	- Lower fuel costs with the pulse do not benefit the crew, on the contrary, slightly lower catch revenue would lead to lower wages
	Crew impact	+ pulse vessels have attracted the best crew with their higher wages encouraging the traditional fishers to invest in pulse trawls to retain their crew.	- lower wages would certainly not attract the most qualified crew already in demand in the fleet
	Social network	+ strong group of pioneers who shared their experience and knowledge through a study group pulse	?
Governance	Government support	+ strong support from the Dutch government through subsidies and release of derogation permits	= No particular support from the Flemish /Belgian government
	Framework encouraging innovation	+ study groups and the fisheries innovation platform were set up by the Dutch government	= No particular support from the Flemish /Belgian government

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