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Testing Theoretical Explanations for Investment Behaviour in the Dutch Beam Trawler Fishery in the North Sea.[1]

by

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Abstract: In this study, we investigate whether neoclassical economic theory, capital market frictions or preference-based theory can explain investment behaviour in the Dutch beam trawler fishery in the North Sea. By presenting a number of estimations, we show that vessels conducting pulse fishing invest substantially more than similar vessels undertaking conventional fishing, even after controlling for differences in such variables as capital stock, prices, profits and quotas. One possible explanation for this result is that vessel owners may obtain a separate benefit from investing in pulse fishing.

[1] This paper was prepared under the FP7 BENTHIS project (312088), but the conclusions do not necessarily reflect the views of the European Commission and do not anticipate the Commission's future policy in this area.

1 Introduction.

In this paper, we analyse investment behaviour in the fisheries sector. The motivation for the paper is the simple observation that the return on capital in many fisheries differs widely between fleet segments. As an example, the return on capital for various fleet segments in Dutch beam trawler fishery in the North Sea is shown in Table 1.[2]

Table 1: Average return on capital in the Dutch beam trawler fishery in the North Sea, 2009-2015.

	Vessels below 12 metres	**Vessels between 12 and 18 metres**	**Vessels between 18 and 24 metres**	**Vessels above 40 metres**
Return on capital (%)	9.8	15.66	21.20	46.20

Source: Own calculations based on Anon (2016).

From Table 1 we see that the return on capital increases with vessel size. For small vessels, the return is in line with the return in other sectors of the economy, whereas the return is huge for very large commercial vessels. A positive relationship between vessel size and return on capital has also been observed in many other fisheries in the European Union (see e.g., STECF, 2017).

The numbers in Table 1 can be related to three strands of economic literature on investments. The first strand of literature can be labelled conventional neoclassical investment theory, and according to that theory, investments should be undertaken until the return on capital is identical between fleet segments.[3] Thereby, neoclassical theory predicts that differences in investments can be explained by a set of key economic variables such as output prices, input prices, interest rates, capital stock, depreciation rate and marginal product of capital. A number of empirical papers within fisheries economics explain variations in investment levels between vessels and/or fleet segments using these variables.[4] However, as the numbers in Table 1 indicate, conventional neoclassical theory may provide a poor explanation for actual investment behaviour in fisheries.

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[2] In this paper we define the return on capital as the interest costs shared by the capital stock measured by the replacement value (see sections 3.2 and 3.3 below). As an alternative the return could be defined as the profit shared by the capital stock.

[3] It is often argued that huge integration on international capital markets implies that the return on capital is approximately identical between countries and industries (see e.g. Campbell et al, 1999).

[4] See e.g. Squires et al. (1994), Campbell et al. (1999), Brandt (2007), Eythorsson (1996), Nostbakken (2012), Jensen et al. (2012), Flaaten et al. (1995), Guyader et al. (2003) and Daures et al. (2006).

The second strand of literature can be labelled modern neoclassical investment theory. According to that theory, a number of capital market frictions exist such as market power, different firm sizes, different market prices, different costs, the use of mark-up pricing, the heterogeneity of firms, licenses (entry barriers), regulation, various forms of uncertainty, the sizes of sunk costs, irreversible investments, subsidies and adjustment costs of capital (see e.g., McLaney et al, 2004 and Lee and Guthrie, 2010).[5] For fisheries, examples of capital market frictions include differences in the regulatory regimes[6], various forms of uncertainty[7] and subsidies such as decommissioning schemes.[8] By using a theoretical model, it can be shown that capital market frictions may cause differences in the return on capital between fleet segments, as in Table 1.[9] Therefore, several empirical studies take capital market frictions into account when explaining differences in investment behaviour between fleet segments.[10]

The third strand of literature can be labelled preference-based investment theory. Nostbakken et al. (2011) argue that differences in the investment behaviours between fleet segments may occur because of differences in preferences of vessel owners. This line of arguments can be traced back to Anderson (1980), who introduced a benefit of being a fisherman. The benefit captures that some fishermen will accept a low remuneration of production factors because the fishing activity itself provides them positive utility. This utility may arise because people enjoy working in nature or because some fishing methods are preferred over other methods due to, for example, perceived environmental friendliness. Anderson (1980) mentioned that the benefit of being a fisherman is higher for small vessels than for large vessels, which may explain the differences in the returns on capital in Table 1.

In this paper, we undertake a first attempt to clarify which theory provides the best explanation for differences in investment levels between fleet segments, and in doing so, we use the Dutch

[5] It can be argued that these variables be labelled market failures. However, we follow Boadway and Bruce (1984) and define market failures as public goods, uncertainty, asymmetric information, externalities and imperfect competition. With this definition, many of the above-mentioned variables cannot be denoted market failures.
[6] See e.g. Cauvin (1979).
[7] See e.g. Singh et al. (2005).
[8] See e.g. Clark et al. (2005).
[9] See e.g. Jensen et al. (2012).
[10] Capital market frictions are included in investment studies within fisheries by e.g. Squires et al. (1994), Campbell et al. (1999), Brandt (2007), Eythorsson (1996), Nostbakken (2012), Jensen et al. (2012), Flaaten et al. (1995), Gyader et al. (2003) and Daures et al. (2006).

beam trawler fishery in the North Sea as an empirical case. In that fishery, vessels engage in pulse (electric) and conventional fishing, and we therefore have two separate fleet segments which operate in a multispecies flatfish fishery mainly targeting sole (*Solea solea*). Sole and other important species are regulated with individual transferable quotas (ITQs), and based on a theoretical model for investment behaviour under that kind of regulation we derive a number of variables that may determine the investments. Our empirical analysis is based on a panel dataset covering 97 vessels for the period between 2009 and 2015[11], and we estimate several different specifications of the theoretical investment model. In all the estimations, we include a dummy variable to capture whether a vessel is undertaking pulse or conventional fishing (a pulse dummy) in order to try to capture preference-based variables. However, we also correct for a number of neoclassical variables and capital market frictions such as capital stock, prices, profits and quotas. We assume that pulse fishing generates a higher benefit of being a fisherman than conventional fishing, for example because it is perceived as being more environmentally friendly. In all the estimated models, the pulse dummy is highly statistically significant, whereas most of the neoclassical variables and capital market frictions are insignificant. The significance of the pulse dummy suggests that differences in the benefits of being a fisherman between pulse and conventional fishing may explain the differences in investments between the two fleet segments. However, despite the fact that we correct for differences in important neoclassical variables and capital market frictions such as profits (and costs)[12], we cannot rule out that the significant pulse dummy is due to omitted variables. One example of an omitted neoclassical variable that may explain differences in investments is differences in expected future returns.

The rest of the paper is organized as follows. In section 2, we present a theoretical investment model for fisheries, whereas section 3 contains descriptions of the fishery and the data. Section 4 provides an overview of the empirical models estimated in our paper, and the results are presented in section 5. The study's conclusions are presented in section 6.

[11] Between 2009 and 2015, a transition in the Dutch beam trawler fishery in the North Sea occurred from conventional to pulse fishing (see Haasnoot et al., 2016).

[12] According to Hamon et al. (2018), the profit in the pulse fishery exceeds that in the conventional fishery and Turenhout et al. (2016) show that fuel costs are lower in the pulse fishery.

2 Theoretical model of investments in fisheries.

Two recent papers, those of Jensen et al. (2012) and Nostbakken (2012), derive theoretical investment models similar to ours. The model in Jensen et al. (2012) applies to a fishery that is regulated with individual non-transferable quotas (INTQs), whereas Nostbakken (2012) considers ITQ regulation. In Nostbakken (2012), long-run investment functions are derived because quota trading is considered as investments and dis-investments. However, there also exist a number of short-run motivations for quota trading[13] such as unpredictable harvests above quotas, and therefore quota trading cannot always be considered an investment.[14] Thus, by assuming short-run motivations for quota trading, we contribute to the analysis in Nostbakken (2012).

We also go beyond Nostbakken (2012) because we introduce two additional modelling features: a. contrary to Nostbakken (2012), the revenue and cost of selling and buying ITQs is included in the objective function (see e.g., Hanley et al, 1997), and b. contrary to Nostbakken (2012), a restriction on the development of quota capital over time is excluded from the model (see e.g., Jensen et al, 2012). In the model, we assume that fishermen can always buy and sell quotas in the short-run[15], implying that a quota restriction does not enter into the fisherman's decision problem.

As an additional difference compared to Nostbakken (2012) and Jensen et al. (2012), we assume that fleet segments (or vessels) differ with respect to a preference-based variable for investing. Specifically, we operate with a fleet-specific exogenous preference for investments in physical capital, α_i. We chose to include α_i in the cost function for investments in physical capital, and we can therefore interpret this function as a perceived cost of investments.[16] α_i can be understood as a benefit of investing in a particular type of gear due to, for example, environmental friendliness. Nostbakken et al. (2011) argue that such factors can be important drivers of investments in fisheries.

[13] See Hanley et al. (1997) for a discussion of short-run explanations for quota trading.

[14] It can be argued that two separate markets for short-run and long-run quota trading exist. However, in actual fisheries we cannot distinguish between these two markets so in this paper we assume that all quota trading is driven by short-run motivations.

[15] See e.g. Andersen et al. (2010) for a discussion.

[16] The results in the paper is not affected by the way α_i is included in the model.

Turning to the model, the profit from investment in physical capital at a current time period, *t*, by fleet segment *i*[17] can be expressed as[18]

$$\pi_{it} = pY_{it} + q(Q_{it} - Y_{it}) - wL_{it} - c(I_{it}, \alpha_i), \tag{1}$$

where π_{it} is the profit earned by fleet segment *i* at time *t*, *p* is a constant output price, Y_{it} is the harvest by fleet segment *i* at time *t*, *q* is a constant price on quotas, Q_{it} is the size of the quota initially distributed to fleet segment *i* at time *t*, *w* is a constant price of variable inputs, L_{it} is the amount of a variable inputs used fleet segment *i* at time *t*, I_{it} is the investments in physical capital by fleet segment *i* at time *t*, and $c(I_{it}, \alpha_i)$ is the perceived costs of investments in physical capital.

Note four facts in relation to (1). First, all variables and parameters on the right-hand side of (1) can be interpreted as vectors, implying that they may contain several variables and parameters. Second, $c(I_{it}, \alpha_i)$ is not necessarily linear in I_{it}, implying that capital may be non-malleable (see e.g., Nostbakken, 2012). Third, we define α_i such that the perceived costs of investments decrease if the exogenous preference-based variable increases ($\frac{\partial c}{\partial \alpha_i} < 0$). Finally, (1) captures both net buyers and net sellers of quotas. If $Q_{it} > Y_{it}$, the fleet segment is a net seller of quotas, and a revenue on $q(Q_{it} - Y_{it})$ is earned from quota trading. Contrarily, provided $Q_{it} < Y_{it}$, the fleet segment is a net buyer of quotas, and a cost on $q(Q_{it} - Y_{it})$ is incurred from quota trading.

Because investments in physical capital are long-run decisions, a dynamic model is needed. We assume discrete time and an infinite time horizon implying that the fisherman's objective function becomes

$$MaxE[\sum_{t=1}^{\infty} \beta^t (pY_{it} + q(Q_{it} - Y_{it}) - wL_{it} - c(I_{it}, \alpha_i)), \tag{2}$$

[17] Note that we can let *i* represent both vessels and fleet segments, but we operate with fleet segments in our paper due to the nature of our dataset (see section 3 below).
[18] See Clark (1990) for an introduction to this model.

where *E* is the expectation operator, and $\beta = \frac{1}{1+r}$ is a discount factor, in which *r* is the interest rate. Based on this definition, we let β be a measure for the interest rate below, and from this, it follows that *r* can be an important explanation for the level of investments in physical capital in fisheries. Remark, also, that fishermen maximize expected rather than actual discounted profit because the size of a fish stock is assumed to be a stochastic variable (see (5) below[19]).

Equation (2) is maximized subject to three constraints. First, a dynamic restriction on the development in physical capital is introduced:

$$K_{it} = I_{it} + (1-\mu)K_{it-1} \qquad \text{for } t = 1, \ldots.., \propto , \tag{3}$$

where K_{it} is the capital stock for fleet segment *i* at time *t*, and μ is a constant depreciation rate. (3) states that the physical capital of fleet segment *i* at time *t* is equal to the investments, I_{it}, plus the capital left over from the previous time period $(1-\mu)K_{it-1}$.

Second, we introduce a production function that summarizes the harvest technology of the fleet segment. Specifically, the production function relates inputs to outputs and can be formulated as

$$Y_{it} = F(L_{it}, K_{it}, S_t) \qquad t = 1, \ldots.., \propto , \tag{4}$$

where S_t is the size of the fish stock at time *t*. Thus, according to (4), the output for a fleet segment at time *t* (Y_{it}) depends on the variable input, the capital stock and the fish stock.

Finally, we take the development in the stock size over time into account. To keep the model simple, we follow Nostbakken (2012) and assume that the fish stock can be expressed as a mean reverting process given by[20]

$$S_t = S_{t-1} + \eta(\overline{S} - S_{t-1}) + z_t \qquad t = 1, \ldots.., \propto , \tag{5}$$

where $\overline{S}$ is the mean stock size, η is the speed of adjustment in stock size and z_t is a random variable with a mean of zero and constant variance (white noise). Note that because z_t is included

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[19] Other stochastic factors may affect the harvest in a fishery but the expectation operator in (2) can also cover these.
[20] See Conrad and Clark (1991) for a discussion of a mean reverting process.

in (5), the fish stock (at time *t*) becomes a stochastic variable, which justifies why an expectation operator is included in (2). Thus, S_t is the expected stock size at time *t*, and due to z_t, the model takes stock uncertainty into account. Since we operate with a fisheries model, it can be argued that (5) should be disregarded as under open-access, but from (2), our model captures long-run behaviour of fishermen. In long-run investment models, it is often argued that fishermen take stock considerations into account (see e.g., Nostbakken, 2012).

Thus, our problem is to maximize (2) subject to (3), (4) and (5) and since we have discrete time this is a dynamic programming problem. To solve the problem, we substitute the production function given by (4) and the dynamic capital equation given by (3) into (2), upon which the Bellman equation becomes[21]

$$\begin{aligned}&v_{it}(K_{it},L_{it},S_t)=pF(L_{it},K_{it},S_t)+q(Q_{it}-F(L_{it},K_{it},S_t))-wL_{it}-\\&c(K_{it}-(1-\mu)K_{it-1},\alpha_i)+\beta^{t+1}E(v_{it+1}(K_{it+1},L_{it+1},S_{it+1},K_{it},\alpha_i)+\\&\sum_{t=1}^{\infty}[\lambda_t(S_t-S_{t-1}-\eta(\bar{S}-S_{t-1})-z_t)],\end{aligned} \tag{6}$$

where λ_t is a Lagrange-multiplier in front of the stock restriction at time *t.* To understand (6), note that the first four terms represent current profit, and $\beta^{t+1}E(v_{it+1}(K_{t+1},L_{t+1},S_{t+1},K_t,\alpha_i)$ is the present value of the maximum expected profit in all future time periods.

In (6), K_{it}, L_{it}, S_t and λ_t are selected as control variables, and the first-order conditions for these variables at a given point in time (*t*) become

$$\frac{\partial v_{it}}{\partial L_{it}}=p\frac{\partial F}{\partial L_{it}}-w_i-q\frac{\partial F}{\partial L_{it}}=0, \tag{7}$$

$$\frac{\partial v_{it}}{\partial K_{it}}=p\frac{\partial F}{\partial K_{it}}-\frac{\partial c}{\partial K_{it}}-q\frac{\partial F}{\partial K_{it}}+\beta\frac{\partial E(v_{it+1})}{\partial K_{it}}=0, \tag{8}$$

[21] The Bellman equation decompose the total discounted profit into the current profit and the maximum value of discounted future profits, which is a well-known method for solving dynamic programming problems (see Conrad and Clark, 1991).

$$\frac{\partial v_{it}}{\partial S_t} = p\frac{\partial F}{\partial S_t} - q\frac{\partial F}{\partial S_t} + \lambda_t + (\eta - 1)\lambda_{t+1} = 0, \text{ and} \tag{9}$$

$$\frac{\partial v_{it}}{\partial \lambda_t} = S_t - S_{t-1} - \eta(\overline{S} - S_{t-1}) - z_t = 0 . \tag{10}$$

According to (7), the value of the marginal product of variable input ($p\frac{\partial F}{\partial L_{it}}$) must equal its marginal costs. The marginal costs consist of the constant price of the input (w_i) and the marginal opportunity cost of holding quotas ($q\frac{\partial F}{\partial L_{it}}$). From (8), the marginal profit of capital at a given point in time is equal to the current value of the expected marginal profit of capital in future time periods ($\beta\frac{\partial E(v_{it+1})}{\partial K_{it}}$). The marginal profit of capital consists of the value of the marginal product of capital ($p\frac{\partial F}{\partial K_{it}}$), the perceived marginal cost of investments ($\frac{\partial c}{\partial K_{it}}$) and the marginal opportunity of holding quotas ($q\frac{\partial F}{\partial K_{it}}$). According to (9), the net value of the marginal product of stock size at a given point in time ($p\frac{\partial F}{\partial S_t} - q\frac{\partial F}{\partial S_t}$) should equal the change in marginal profit due to stock size in future time periods represented by $\lambda_t + (\eta - 1)\lambda_{t+1}$.[22] Finally, (10) is the restriction on the stock size described by (5).

(7), (8), (9) and (10) can be solved to find optimal values for K_{it}, L_{it}, S_t and λ_t, which we label K_{it}^*, L_{it}^*, S_t^* and λ_t^*, respectively. K_{it}^*, L_{it}^*, S_t^* and λ_t^* will depend on all the constant (time independent) parameter values in the model ($q, w, p, \beta, \alpha_i, \mu$ and η) and due to the recursive nature of the model, the optimal solutions will also depend on all future values of the relevant variables. However, we assume adaptive expectations, so instead of future values, we use lagged

[22] Due to the mean reverting process describing the development in the stock size in (5), the change in marginal profit in future time periods is included because harvesting one unit of fish now implies lower stock sizes in future time periods.

values of the variables.[23] The lagged variables can be treated as exogenous, and, for simplicity, we assume that the maximum number of lags included in the model is one. These considerations imply that K_{it}^*, L_{it}^*, S_t^* and λ_t^* also depend on $K_{it-1}, S_{t-1}, L_{t-1}, \lambda_{it-1}, Q_t, Q_{t-1}, z_t$ and z_{t-1}.

K_{it}^*, L_{it}^* and S_t^* can now be inserted into (4) to obtain the optimal harvest of a fleet segment (Y_{it}^*), and Y_{it}^* will also depend on the parameter values and lagged variable. K_{it}^* can also be inserted into the dynamic capital constraint in (3) (given by $I_{it} = K_{it} - (1-\mu)K_{it-1}$), so the optimal level of investments in physical capital becomes

$$I_{it}^* = I_{it}^*(K_{it-1}, S_{t-1}, L_{it-1}, \lambda_{it-1}, Q_t, Q_{t-1}, z_t, z_{t-1}, q, w, p, \beta, \alpha_i, \mu, \eta). \tag{11}$$

(11) is the theoretical investment relation we depart from in this paper, and two facts are important in relation to (11). First, α_i enters into the cost function for investments, and because we assume that $\frac{\partial c}{\partial \alpha_i} < 0$, we obtain that $\frac{\partial I_{it}^*}{\partial \alpha_i} > 0$. Thus, an increase in the exogenous preference-based variable will increase the level of investments. Second, in (11), the harvest (Y_{it}), lagged capital stock (K_{it-1}), lagged fish stock (S_{t-1}), lagged variable input (L_{t-1}), lagged shadow price on stock size (λ_{it-1}), output price (*p*), input price (*w*), interest rate (β), stock adjustment factor (η) and depreciation factor (μ) represent neoclassical variables. α_i captures a vessel-specific preference-based variable, whereas the quota (Q_t and Q_{t+1}), price on quotas (q) and size of stock uncertainty (z_t and z_{t-1}) can be interpreted as capital market frictions.

3 Fishery and data.

3.1 A description of the Dutch beam trawler fishery in the North Sea.

In this paper, we use the Dutch beam trawler fishery in the North Sea as an empirical case. Approximately 60 vessels larger than 40 metres participate in this fishery, and the fishery is very important for the Netherlands. In 2012, the fleet "produced" 20% of the total fishing effort in the

[23] Adaptive expectations cover that a current value of a variable is explained by lagged values of the variable. Operating with adaptive expectations in investment models for fisheries is a common practice in the literature (see e.g. Nostbakken, 2012 and Jensen et al, 2012).

Dutch fisheries industry and generated 20% of the employment (see Anon, 2016). The Dutch beam trawler vessels in the North Sea mainly target sole and plaice because those two species account for approximately 80% of the total landings of all species (see Anon, 2016). Plaice represents 60% of the landings in volume but only accounts for 26% of the landing value (see Anon, 2016). In contrast, sole only represents 19% of the landing in volume but 54% of the landing value (see Anon, 2016). In this paper, we will use sole as the main targeted species in single-species models, but we also investigate multi-species models in which the harvest of all species, including plaice, is included.

The vessels in the Dutch beam trawler fishery in the North Sea mainly undertake pulse and conventional fishing[24], and in this paper, we will distinguish between those two kinds of fishing. Conventional fishing is described in numerous papers, and it is well-known that this method may cause damage to biogenic structures at the bottom of the sea because mechanical stimulation (ticker chains) is used to chase flatfish out of the seabed (see e.g., Collie et al, 2000 and Kaiser et al, 2006). Thus, considerable effort has been devoted to developing pulse fishing, in which electric stimulation is used as an alternative to mechanical stimulation (see e.g., Collie et al, 2000 and Kaiser et al, 2006). Specifically, the heavy ticker chains used in conventional fishing are replaced with lightweight electrodes.

From the middle of the 1980s and up until the middle of the 2000s, pulse fishing was illegal within the European Union. However, in 2008, the Dutch government provided subsidies for investments in 5 trial vessels undertaking pulse fishing, and since then, pulse fishing has increased in popularity (see e.g., Haasnoot et al, 2016). In 2014, approximately 80 vessels were allowed to undertake pulse fishing in the North Sea, but to undertake pulse fishing, vessels have to apply for a license, which are randomly allocated to some of the vessels applying for a permit (see e.g., Haasnoot et al, 2016). Despite an increasing number of studies[25], the true environmental impacts of pulse fishing are not yet fully understood, but several studies indicate that fishermen perceive pulse fishing as more environmentally friendly than conventional fishing because of the use of electronic

[24] Conventional fishing is represented by traditional trawling and trawling by sumwing.
[25] See van Beek et al. (1990), de Haan et al. (2016), Desender et al. (2017a), Desender et al. (2017b), ICES (2017), Soetaert et al. (2015), Soetaert et al. (2016a), Soetaert et al. (2016b), Soetaert et al. (2016c), Soetaert et al. (2016d) and van der Reijden et al. (2017).

simulation instead of the heavy tickler chains (see Jennings and Kaiser, 1998, Polet and Depestle, 2010, van Marlen et al 2014 and Turenhout et al, 2016). In addition, pulse fishing also increases the profits in the fishery because fuel costs are reduced due to the use of electric instead of mechanic stimulation (see Hamon et al, 2018 and Turenhout et al, 2016).[26] Furthermore, as indicated by Jennings and Kaiser (1998) and Polet and Depestle (2010), vessel owners expect higher future returns when conducting pulse instead of conventional fishing.

3.2 Investments.

For the Dutch beam trawler fishery in the North Sea, we have a panel dataset from Anon (2016) that covers a population of 97 vessels fishing for the period between 2009 and 2015, and in that period, the number of vessels undertaking pulse fishing increased. The dependent variable in our models is the total investments in physical capital which, in the dataset, is decomposed into three categories: a. the value of all investments in hulls, motors and gear that are related to the pulse fishery, b. the value of small investments that are not related to hulls, motors and gear or to the pulse fishery, and c. the value of large investments in hulls, motors and gear that are not related to the pulse fishery. To obtain a measure of the total investments in physical capital, we aggregated the investments in these three categories. Note that because a., b. and c. will vary between vessels and years, our measure of investments will do the same.

In Table 2 below, we present summary statistics for the size of the total investments covering all years and all vessels.

From Table 2, we see that for vessels conducting both pulse and conventional fishing, the mean value of the investments is low, but the mean value of the investments is much higher for vessels conducting pulse rather than conventional fishing.

[26] Based on our dataset, we are able to show that the profit in the pulse fishery generates a significant higher profit than in the conventional fishery. Thereby, we can confirm the results in Hamon et al. (2018) and Turenhout et al. (2016). .

Table 2: Summary statistics for the Dutch beam trawler fishery in the North Sea, 2009-2015.

		Pulse fishing					Conventional fishing				
	Measurement units	**Number of observations**	**Mean**	**Standard derivation**	**Minimum value**	**Maximum value**	**Number of observations**	**Mean**	**Standard derivation**	**Minimum value**	**Maximum value**
Dependent variable											
Investments	1000 Euro	79	71.87	95.85	0.00	374.50	135	23.91	52.12	0.00	431.00
Neoclassical variables											
Capital stock	1000 Euro	79	640.68	527.72	71.42	2,194.60	135	280.10	403.86	22.88	2,234.23
Total harvest	Tons	79	451.20	147.41	123.47	1,111.08	135	236.02	229.46	21.28	893.38
Price on all harvest	1000 Euro/tons	79	4.29	0.96	2.46	6.89	135	3.37	0.66	1.49	4.70
Total harvest of sole	Tons	79	125.09	43.12	3.07	229.32	135	10.83	30.95	0.00	151.22
Price on sole	1000 Euro/tons	79	9.74	1.16	7,58	12.55	135	9.85	2.14	6.22	17.02
Interest rate	%	79	3.12	3.17	1.43	21.27	135	3.46	4.30	0.68	23.77
Capital market frictions											
Quota of all species	Tons	79	383.08	249.95	1.68	1,432.09	135	89.18	163.92	0.00	634.48
Quota price on all species		79	5.64	1.59	0.27	9.33	97	6.57	2.38	1.17	16.13
Quota of sole	Tons	79	70.18	36.39	0.42	151.82	135	12.72	25.68	0.00	104.38
Quota price on sole		79	20.51	6.32	12	28	95	18.15	6.33	12	28
Preference based variable											
Pulse dummy	0 or 1	79	1.00	0.00	1	1	135	0	0	0	0
Additional variables											
Profit	1000 Euro	79	229.72	244.28	-420.90	791.21	135	71.15	106.51	-262.34	419.19
Construction year	Year	79	1,995	5.96	1980	2004	134	1,976	19.41	1923	2007
Vessel tonnage	1000 gross tonnage	79	0.40	0.14	0.09	0.56	135	0.13	0.14	0.01	0.55

Source: Own calculations based on Anon (2016).

3.3 Neoclassical variables.

To capture the neoclassical variables, we include a. the capital stock, b. the harvest of all species, c. the harvest of sole, d. the ex-vessel price of all species, e. the ex-vessel price of sole and f. the interest rate. We measure variable a. with the replacement value, which was calculated by Anon (2016) using hull age and construction year. We have information about b. and c. directly from the dataset, and when using b. (and d.) in a model, we impose a multi-species assumption, whereas the use of c. (and e.) represents a single-species assumption. Concerning d. and e., we have information about the revenue from each vessel's harvest, and by dividing that with the harvest, we obtain the unit value, which serves as our proxy for the price. Note that this calculation procedure leads to prices that differ between vessels as well as years. Our measure of f. is the total interest costs divided by the capital stock (replacement value), and in this way, the interest rate will also vary between vessels and years.

From Table 2, we see that the mean value of the capital stock, the harvest of all species and the harvest of sole are higher for vessels undertaking pulse instead of conventional fishing. Conversely, the price of all species, the price of sole and the interest rate were almost identical for pulse and conventional fishing. By looking at the minimum and maximum values, it appears that there are numerous variations in the observations for the capital stock and the total harvest of all species. Finally, from the minimum values, we observe that all observations of the neoclassical variables are positive.

3.4 Capital market frictions.

To capture capital market frictions, we include a. the quota on all species, b. the quota on sole, c. the quota price on all species and d. the quota price on sole. In relation to a. and b., we have information about these variables directly from the dataset; a. represents a multi-species assumption, whereas b. captures a single-species assumption. For c. and d., we have information about the value of the holding of quotas such that a quota price can be calculated by dividing that value by the quota. Thus, we obtain in principle a vessel and year specific quota price, but due to the way the value of the quota on sole is defined in Anon (2016), there is no variation in d. between vessels (see Table 2), whereas c. will vary between vessels.

From Table 2, we see that the mean values of both the quota of all species and the quota of sole are high, and the same holds for the two quota prices. Furthermore, the mean values of the quotas on both all species and sole are higher in the pulse than in the conventional fishery. Finally, all the observations for the capital market frictions were positive.

3.5 A preference-based variable.

To clarify whether preference-based theory can explain investments in the Dutch beam trawler fishery in the North Sea, we include a pulse dummy with a value on 1 if a vessel undertakes pulse fishing and a value of 0 if conventional fishing is conducted. If the parameter in front of the pulse dummy turns out to be positive and significant in the estimated models, this means that vessels undertaking pulse fishing invest more than similar vessels conducting conventional fishing. Since we control for factors that ought to influence the investment level, a positive and significant pulse dummy may suggest that a preference-based variable (the benefit of being a pulse fisherman) is an important determinant of investments. This finding may be observed because pulse fishing is perceived as more environmentally friendly by vessel owners than conventional fishing, even though scientific information on this issue is incomplete (see section 3.1).

3.6 Additional variables.

In line with the empirical literature on investments in fisheries, we include three additional variables in our regression models, which are, however, not derived from the theoretical model in section 2: a. vessel construction year; b. vessel size and c. a measure of profit in the pulse and conventional fisheries. In relation to a., Jensen et al. (2012) finds that vessel construction year is important for the sizes of investments, and we therefore take this variable into account in the estimations.[27] For b., we measure this variable with vessel tonnage, and here Nostbakken (2012) finds that vessel tonnage is important when explaining investments in fisheries. Regarding c., we mentioned in section 3.1 that pulse fishery generates a considerably higher profit than conventional fishery, and following Nostbakken et al. (2011), it is useful to include a measure for the profit of each vessel.[28]

[27] Because these variables are not derived from the theoretical model, we are not interested in predicting the signs of the coefficients in front of them. However, we will expect that a. a lower construction year (an older vessel) implies higher investments, b. a higher tonnage implies higher investments and c. a higher profit generates a higher investment.

[28] Note that neoclassical theory will imply that the marginal profit is identical between fleet segments and, therefore, we choose to label the profit of vessels as an additional variable, although it can also be interpreted as a neoclassical variable (and a capital market friction).

By looking at Table 2, we can confirm that the profit is higher in the pulse fishery than in the conventional fishery and that there are a large number of observations with negative profits in the dataset (approximately 100 observations).

4 Empirical models.

From section 2, we have that K_{it}^*, L_{it}^*, S_t^* and λ_t^* could be found by solving four equations with four unknowns and that K_{it}^*, L_{it}^*, S_t^* and λ_t^* will depend on the parameter values and lagged values of the variables included in the model. Furthermore, K_{it}^* can be inserted into (3) to find the investment function in (11), but instead of using that procedure, we depart directly from (11). However, this may cause endogeneity problems due to the existence of K_{it}^*, L_{it}^*, S_t^* and λ_t^*, but to minimize the endogeneity problems, we may consider including L_{it}, K_{it}, S_t and λ_{it} directly in (15) as an approximation. Regarding K_{it}, it is natural to include this variable because capital stock is closely related to investment throughout the dynamic capital constraint in (3). With respect to L_{it}, we must expect that there is low variation in this variable over time and between the vessels. For the fish stock, there is no variation in the variable between vessels and a low variation between years. Therefore, excluding the variable input and fish stock seems reasonable despite the problems with endogeneity.[29] Regarding λ_{it}, this variable is unobserved, so this shadow price must be omitted from the model, and z_t, z_{t-1} μ and η are also relegated to the error term because they are unobservable. Furthermore, we have no information regarding input price, depreciation rate and stock adjustment factor, and therefore those parameters must also be excluded. Finally, because capital stock is included in the estimations, it is also useful to take the harvest (Y_{it}) into account. Therefore, in total, we reach the following investment function, which can be estimated using our dataset:

$$I_{it} = I_{it}(K_{it}, K_{it-1}, Y_{it}, Q_t, p, q, \beta, \alpha_i) . \tag{12}$$

[29] Due to the variations in the variable input and fish stock between years, it can be argued that yearly dummies should have been included in the estimations. However, we have been estimating our models by including yearly dummies, and in all the estimated models, the year dummies turned out to be insignificant. Therefore, we have chosen to report our results without yearly dummies.

By using the considerations below (11) in relation to (12), the capital stock (K_{it} and K_{it-1}), the harvest (Y_{it}), output price (*p*) and interest rate (β) represent neoclassical variables, and the α_i capture the preference-based variables. Finally, the quota (Q_t) and the price on quotas (q) can be interpreted as capital market frictions. Furthermore, we will expect that vessels undertaking pulse fishing invest more than vessels conducting conventional fishing, implying that $\frac{\partial I_{it}}{\partial \alpha_i} > 0$.

To discuss whether neoclassical variables, capital market frictions or preference-based variables explain investments in the Dutch beam trawler fishery in the North Sea, we conduct a first-order approximation of the general investment model in (12). Based on that approximation, we have estimated two different models given by

$$I_{it} = a + b * PS + \sum_{j=1}^{n} c_j x_{ijt} + f \pi_{ijt-1} + e_i \qquad \text{(model 1),} \qquad (13)$$

$$I_{it} = a + b * PS + \sum_{j=1}^{n} c_j x_{ijt} + \sum_{j=1}^{n} d_j x_{ijt-1} + f \pi_{ijt-1} + e_i \qquad \text{(model 2),} \qquad (14)$$

where *a, b,* c_j, d_j and *f* are estimated parameters, x_{ijt} are explanatory variables, x_{ijt-1} are the lagged values of explanatory variables, *PS* is the pulse dummy, π_{ijt-1} is the lagged value of the profit, and e_i is a random error term. In the following, we refer to x_{ijt} as the non-lagged variable, whereas x_{ijt-1} is a lagged variable, and in model 1, we assume that all the variables, apart from the profit, are non-lagged. This is consistent with a situation where all the variables are in steady-state equilibrium[30], but based on the theoretical model in section 2, an assumption about an absence of lags does not seem reasonable. Therefore, we extend model 1 to allow for lagged variables, and we label this model 2. In (12), we only include the lagged value of the capital stock, but in the estimations, we determined the variables on which a lag was introduced according to significance. This implies that we include lags on the capital stock, the interest rate, the quota and the quota price.

From section 3.1, we have that pulse and conventional fishing profits differ. However, from a statistical point of view, it is problematic to include the profit in an investment function because

[30] See e.g. Clark (1990).

the profit and investments ((13) or (14)) are simultaneously determined, implying that the profit is endogenous. To solve this problem, we include the lagged profit (π_{ijt-1}) in (13) and (14)[31], and by doing so, we assume that past profits are unaffected by present profits.[32]

In relation to (13) and (14), we must also decide whether to estimate the models with levels or logarithmic values of the variables. In this instance, it is important that the profit is negative for approximately 100 observations in the dataset (see Table 2) and that the profit is higher for pulse than for conventional fishing. Since the logarithmic function is undefined for negative numbers, this implies that a logarithmic specification of all variables in (13) and (14) will underestimate the difference in investments between pulse and conventional fishing because the observations with negative profits mainly arose for vessels undertaking the latter.[33] Another option is to take the logarithmic value of all variables apart from the profit, but we prefer to measure all variables in (13) and (14) in the same units. Thus, we chose to estimate (13) and (14) by using the variables in levels.

In the estimation of the two models, we also have to decide whether to impose a single-species or multi-species assumption. Here, we chose to present results departing from both assumptions, which implies that we estimate two versions of both model 1 and 2: a. estimation of (13) and (14) using output price, quantity, quota price and quota of all fish species corresponding to an assumption of a multi-species fishery and b. estimation of (13) and (14) using output price, quantity, quota price and quota of sole corresponding to an assumption of a single-species fishery. Furthermore, because we have a panel dataset, it is also possible to control for vessel-specific fixed effects. For that reason, we estimated each specification of models 1 and 2 by a. ordinary least squares (labelled Pooled) and b. vessel-specific fixed effects (labelled Within). We test for whether vessel-specific fixed effect arises with an FE-test.

In (13) and (14), we only allow vessels undertaking pulse and conventional fishing to differ with respect to the constant term. However, the two groups of vessels might also differ with respect to

[31] Another solution to the problem with endogeneity is to use instrument variable estimation but this requires that suitable instruments can be found, and we have not been able to do this for our dataset.
[32] Another argument for including the lagged profit is that investment is affected by past profits and not present profits.
[33] We have tried to estimate our models by using logarithmic values of the variables, and when doing so, the pulse dummy becomes insignificant in all models.

the coefficients to the explanatory variables. To test for this kind of structural differences between pulse and conventional fishery, we carried out a Chow-test for equality of the coefficients to the explanatory variables between the two groups of vessels.[34] Such structural differences between fleet segments are normally not discussed in investment models within fisheries. In the theoretical model in section 2, structural differences will imply that the pulse and conventional fisheries have separate investment functions.

A potential problem with our regressions is that self-selection bias may arise because the fishermen decide whether or not to undertake pulse fishing. If the factors that influence the decision to undertake pulse fishing also influence the level of investments, then the pulse dummy is endogenous. However, we believe that self-selection bias has had a minor impact on our results because vessels have to apply for a license before pulse fishing can be conducted, and the licenses are randomly allocated among fishermen who apply for the fishing rights (see section 3.1).

5 Results.

5.1 Model 1.

The results from estimating the two specifications of model 1 are reported in Tables 3 and 4.

[34] See Johnston and DiNardu (1997) for a discussion of the Chow-test.

Table 3: Estimation results under a multi-species assumption.

	Pooled	**Within**
Constant term	119.006 (528.264)	
Neoclassical variables		
Capital stock	0.004 (0.012)	0.019 (0.027)
Total harvest	-0.022 (0.041)	-0.044 (0.105)
Price on all harvest	-5.951 (6.721)	-8.649 (8.887)
Interest rate	0.0004 (0.001)	-0.0004 (0.001)
Capital market frictions		
Quota of all species	-0.023 (0.044)	-0.230 (0.144)
Quota price on all species	1.868 (1.934)	1.901 (3.891)
Preference based variables		
Pulse dummy	51.254*** (15.376)	79.122*** (27.607)
Additional variables		
Lagged profit	0.011 (0.037)	0.108 (0.072)
Construction year	-0.050 (0.265)	-7.726*** (2.665)
Vessel tonnage	118.493*** (45.654)	700.471* (385.383)
Statistical tests and information		
Chow test (p-value)	0.006	0.001
FE test (p-value)		0.91
R^2	0.179	0.113
Observations	269	269

Note: * indicates p <0.1; ** indicates p < 0.05; *** indicates p < 0.01.

Source: Own estimations.

Table 4: Estimation results under a single-species assumption.

	Pooled	**Within**
Constant term	-373.994 (1108.953)	
Neoclassical variables		
Capital stock	0.005 (0.014)	0.002 (0.037)
Total harvest of sole	-0.555** (0.276)	-1.285*** (0.538)
Price on sole	4.501* (2.639)	2.655 (3.491)
Interest rate	0.001 (0.001)	-0.00002 (0.001)
Capital market frictions		
Quota of sole	0.049 (0.260)	-1.762** (0.812)
Quota price on sole	-0.462 (0.760)	-3.068*** (1.184)
Preference based variables		
Pulse dummy	72.404*** (16.865)	108.671*** (27.598)
Additional variables		
Lagged profit	0.032 (0.043)	0.104 (0.067)
Construction year	0.171 (0.564)	-5.873** (2.849)
Vessel tonnage	165.772** (64.507)	1894.051*** (607.196)
Statistical tests and information		
Chow test (p-value)	0.089	0.045
FE test (p-value)		0.73
R^2	0.180	0.211
Observations	200	200

Note: * indicates $p < 0.1$; ** indicates $p < 0.05$; *** indicates $p < 0.01$.

Source: Own estimations.

Let us first discuss the signs of the coefficients to the neoclassical variables in Tables 3 and 4. Regarding capital stock, we have two counteracting effects regarding its influence on investments: a. a high capital stock indicates a high return on capital, making investments more profitable and b. a high capital stock implies that less investment are needed to reach a target capital stock. The positive coefficients to the capital stock in Tables 3 and 4 indicate that the former effect dominates the latter. Concerning the total harvest of all species (the multi-species models in Table 3), there are also two counteracting effects: a. an increase in the harvest may indicate high profitability from fishing, leading to higher investments and b. an increase in the harvest leads to a decrease in the fish stock, implying lower investments. The negative coefficients to the total harvest indicate that explanation b. dominates a. When looking at the harvest in the single-species models (the harvest of sole in Table 4), we also obtain a negative coefficient, and the explanation for that result is the same as for the multi-species model. For the output price in the multi-species model, the sign of the coefficient is negative in Table 3, but this seems to be an unexpected result. However, in a multi-species fishery an increase in the average price may imply that fish of higher value is harvested which make investments less necessary. In the single-species model in Table 4, the sign of the coefficient to the output price is positive, which is as expected because a price increase leads to an increase in the profitability of the harvest. For the interest rate, we obtained ambiguous signs in the models. In Pooled in Table 3, the sign of the coefficient to the interest rate is positive, whereas the signs were negative in the three other models. This difference in the signs is probably because the interest rate was calculated as the interest costs divided by the capital stock (see section 3.2). Thereby, an increase in the interest rate can reflect both an increase in the interest costs and a decrease in the capital stock.

For the capital market friction, the sign of the quota coefficient is negative in three out of the four models (see Tables 3 and 4). An explanation for this result is that an increase in a quota can have counteracting effects on investments depending on whether a vessel is a net buyer or net seller of quotas. Concerning the quota price, this variable had a positive effect on the investments in three out of the four models, and as for the quota, the effect of the quota price on investments depends on whether the vessel is a net buyer or seller of quotas. To summarize the above considerations, the signs in front of the included neoclassical variables and capital market frictions seem to be reasonable for the models without lagged variables.

Turning to the statistical significance of the neoclassical variables and capital market frictions, none of the variables is significant in the multi-species models in Table 3. In the singles-species models in Table 4, the total harvest of sole is significant at a 5%-level in Pooled and at a 1%-level in Within. Furthermore, both the quota and quota price on sole are significant in Within in Table 4. Regarding the additional variables, vessel tonnage is significant in all models (at a 1%-5% or 10% level), and construction year is significant in both Within models in Tables 3 and 4. Finally, slightly surprisingly, the lagged value of the profit only has an insignificant effect on investments. Thus, the overall conclusion is that the neoclassical variables, the capital market frictions and additional variables provide a poor explanation for investment behaviour in the Dutch beam trawler fishery in the North Sea.

By looking at the pulse dummy in Tables 3 and 4, we observe that this variable is statistically significant at the 1% level in all models. From sections 2 and 3, the pulse dummy can be interpreted as an exogenous preference-based variable for investing in the pulse fishery. Thus, if we correct for the influence of several neoclassical variables and capital market frictions that potentially can affect the dependent variable, the investments are higher in the pulse fishery than in the conventional fishery. This conclusion can be strengthened by looking at the economic significance of the pulse dummy in Tables 3 and 4. Because the investments are measured in 1000 EURO, the coefficient in front of the pulse dummy indicates that vessels undertaking pulse fishing, on average, invest between 56,786 EURO and 133,228 EURO more than vessels conducting conventional fishing. Thus, from an economic perspective, the investments are significant higher in the pulse fishery than in the conventional fishery. In total, these observations lead to the conclusion that fishermen may obtain a separate benefit from investing in the pulse fishery. However, we cannot rule out that omitted neoclassical variables and capital market frictions can explain the positive and highly significant pulse dummy. Specifically, the pulse dummy can capture differences in the expectations to future return between pulse and conventional fishing.

Four additional results can be mentioned in relation to Tables 3 and 4. First, R^2 is fairly low in all the models in Tables 3 and 4, implying that only a minor part of the variation in the investments is explained. Second, from Tables 3 and 4, we observe that the p-value of the FE-test is very high in both the multi-species and single-species models. Thus, despite the fact that we have a panel dataset, it is reasonable to operate with a common constant term for all vessels (apart from the pulse dummy). Third, as mentioned in section 4, we have also performed a Chow-test for all the models to determine whether the coefficients to the explanatory variables differ between pulse and conventional fishing. The p-values for this test are also reported in Tables 3 and 4, and in all models, the p-value is so low[35] that it can be concluded that the estimated coefficients differ between the pulse and conventional fishery. Thus, structural differences in the investment functions between the vessels undertaking pulse and conventional fishing may exist. Finally, we have not investigated whether the vessels conducting pulse fishing invest more because of the gear used or because they invest more in general. To investigate this issue, we have estimated all the models by using non-pulse related investments instead of total investments including pulse related investments. In these estimations, the pulse dummy turns out to be insignificant, which indicates that vessels conducting pulse fishing may invest more because of the gear used.

5.2 Model 2.

A potential problem with the estimations in Tables 3 and 4 is that we have not included lagged variables, but according to the theoretical model from section 2, they ought to be taken into account. For that reason, we have included lags in capital stock, interest rate, quota and quota price. As mentioned in section 4, we have chosen the variables for which lagged values are included according to significance, and the estimation results are presented in Tables 5 and 6.

[35] 0.006 and 0.001 in the multi-species model in Table 3 and 0.089 and 0.045 in the single-species model in Table 4.

Table 5: Estimation results under a multi-species assumption.

	Pooled	**Within**
Constant term	-45.087 (612.059)	
Neoclassical variables		
Non-lagged capital stock	0.120 (0.150)	0.352 (0.321)
Lagged capital stock	-0.108 (0.141)	-0.333 (0.329)
Total harvest	-0.022 (0.040)	-0.072 (0.089)
Price on all harvest	-5.970 (6.989)	-7.173 (8.626)
Non-lagged interest rate	0.001 (0.001)	0.0004 (0.001)
Lagged interest rate	-0.001 (0.001)	-0.002 (0.001)
Capital market frictions		
Non-lagged quota of all species	-0.195 (0.119)	-0.744*** (0.275)
Lagged quota of all species	0.244* (0.143)	0.631** (0.286)
Non-lagged 1quota price on all species	-0.951 (2.384)	-3.287 (4.301)
Lagged quota price on all species	5.700** (2.316)	7.333* (2.988)
Preference based variables		
Pulse dummy	56.786*** (14.405)	81.495*** (23.048)
Additional variables		
Lagged profit	-0.012 (0.043)	0.077 (0.073)
Construction year	0.026 (0.307)	-3.841 (4.685)
Vessel tonnage	93.155** (46.135)	771.292** (373.920)
Statistical tests and information		
Chow test (p-value)	0.001	0.003
FE test (p-value)		0.73
R^2	0.202	0.175
Observations	268	268

Note: * indicates p <0.1; ** indicates p < 0.05; *** indicates p < 0.01.

Source: Own estimations.

Table 6: Estimation results under a single-species assumption.

	Pooled	**Within**
Constant term	-710.872 (1124.158)	
Neoclassical variables		
Non-lagged capital stock	0.171 (0.158)	0.266 (0.531)
Lagged capital stock	-0.154 (0.147)	-0.254 (0.537)
Total harvest of sole	-0.538** (0.243)	-1.474*** (0.343)
Price on sole	3.268 (3.694)	3.529 (5.481)
Non-lagged Interest rate	0.002** (0.001)	0.0004 (0.002)
Lagged interest rate	-0.001 (0.001)	-0.001 (0.002)
Capital market frictions		
Non-lagged quota of sole	-0.101 (0.458)	-1.646 (1.128)
Lagged quota of sole	0.175 (0.328)	2.816*** (0.814)
Non-lagged quota price on sole	-1.556 (3.217)	-4.416 (4.755)
Lagged quota price on sole	1.995 (4.721)	2.866 (6.864)
Preference based variables		
Pulse dummy	72.784*** (16.888)	133.228*** (22.256)
Additional variables		
Lagged profit	0.022 (0.045)	0.120* (0.062)
Construction year	0.345 (0.573)	-2.496 (4.424)
Vessel tonnage	169.539*** (59.193)	1528.295** (645.655)
Statistical tests and information		
Chow test (p-value)	0.068	0.005
FE test (p-value)		0.33
R^2	0.186	0.277
Observations	200	200

Note: * indicates p <0.1; ** indicates p < 0.05; *** indicates p < 0.01.

Source: Own estimations.

Regarding the sign of the estimated coefficients to the neoclassical variables, a positive coefficient is obtained for the non-lagged capital stock, and a negative coefficient is reached for the lagged value of this variable. The former is explained by the fact that a high capital stock indicates a high return on capital, making investments more profitable, whereas the latter captures that a high capital stock indicates that less investments are needed to reach a target stock of capital. Regarding the interest rate, the sign of the coefficient to the non-lagged variable is positive in all models in Tables 5 and 6, whereas the lagged variable is negative. As mentioned in connection with Tables 3 and 4, this is probably due to the way the interest rate is calculated.

Regarding capital market frictions, the sign of the coefficient to the non-lagged quota is negative, whereas the sign of the lagged quota is positive in both the multi-species and the single-species models. These signs can probably be explained by distinguishing between net buyers and net sellers of quotas. For the quota price, the sign of the coefficient to the non-lagged variable is negative, whereas the sign to the lagged variable is positive in both Tables 5 and 6. These signs can also be explained by distinguishing between quota selling and buying. Thus, in total, the signs in front of the neoclassical variables and capital market frictions become reasonably theoretically consistent when lagged variables are included. Therefore, judged by the signs of the included variables, the dynamic investment model in section 2 seems reasonable.

Regarding the statistical significance of the neoclassical variables, we see from Table 5 that none of the variables are significant in the multi-species model, whereas only the non-lagged total harvest of sole is significant in the single-species model. For the capital market frictions in the multi-species model (Table 5), both the lagged quota and quota price are significant in Pooled. However, in the single-species model, both the non-lagged and lagged quotas are significant in Within, together with the lagged quota price. For the additional variables, vessel tonnage is significant in both Tables 5 and 6 as in the models without lags in Tables 3 and 4, whereas the lagged value of the profit is insignificant as in section 5.1.

As in section 5.1, the pulse dummy is highly statistically significant in all four models. Thus, we can conclude that vessels undertaking pulse fishing invest significantly more than vessels conducting conventional fishing, even when we include lagged values of some of the neoclassical variables and capital market frictions. Concerning economic significance, vessels undertaking pulse fishing invest between 56,786 EURO and 133.228 EURO more than vessels conducting conventional fishing. Furthermore, the sizes of the additional investments by vessels undertaking pulse fishing in the models with and without lags are in line with each other (comparing the results in section 5.1. and in this section). Thus, from the point of view of economic significance, it does not matter whether we include lagged variables. In total, these results indicate that the benefit of being a fisherman is higher in the pulse fishery than in the conventional fishery. However, the positive and significant pulse dummy can also be due to omitted neoclassical variables and capital market frictions represented by, for example, differences in the expected future returns between fleet segments.

Four additional conclusions can be summarized with respect to the models with lagged variables. First, by comparing Tables 3 and 4 with Tables 5 and 6, we see that there is a slight increase in R^2 when lagged values of the independent variables are included. However, R^2 is still fairly low, so even when including lagged variables, a low amount of the variation in the investments is explained. Second, from Tables 5 and 6, we also see that the p-value on the FE-test in both models is high.[36] Thus, a fixed effect model does not seem to be necessary, and we can operate with identical constant terms for all vessels in the four models (apart from the pulse dummy). Third, for the Chow-test, the p-value is low in all four models.[37] Thus, it seems likely that the estimated parameters will differ between pulse and conventional fishing, indicating that the investment functions are structurally different. Finally, as in section 5.1, the pulse dummy becomes insignificant if the non-pulse related investments are used as a dependent variable. This indicates that vessels conducting pulse fishing invest more because of the fishing gear used.

6 Conclusions.

A common observation in actual fisheries is that the return on capital differs considerably between fleet segments, but according to conventional neoclassical theory, investments should be allocated such that the return on capital becomes identical for all vessels. One implication of neoclassical theory is that investments in various fleet segments can be explained by several key economic variables. Alternatives to neoclassical theory are: a. modern neoclassical theory, in

[36] 0.73 and 0.33.

[37] 0.001, 0.003, 0.068 and 0.005.

which capital market frictions partly explain investments, and b. preference-based theory, where fishermen obtain a separate benefit from investing. Both alternative theories offer an explanation for why the return on capital may differ between fleet segments.

In this paper, we have investigated which factors can explain investments in the Dutch beam trawler fishery in the North Sea. By using a theoretical model, we derived a number of neoclassical variables, capital market frictions and preference-based variables that potentially may affect investments. In the empirical models we measure the preference-based variable with a pulse dummy measuring whether a vessel undertaking pulse or conventional fishing.

We have undertaken a number of estimations where relevant neoclassical variables, capital market frictions and the pulse dummy variable are included. Specifically, we a. estimated multispecies and single-species models using output prices, quota prices, harvest and quotas for both all species and sole, b. estimated models with OLS and fixed effects and c. estimated models with and without lagged values of the independent variables. In all the estimated models, the pulse dummy is highly statistically and economically significant, whereas most of the neoclassical variables and capital market frictions are statistically insignificant. One implication of this result is that a fisherman may obtain a separate benefit of investing in pulse fishing because that method is perceived as more environmentally friendly. However, the positive and significant pulse dummy can also be due to differences in omitted neoclassical variables and capital market frictions. In particular, the significant dummy variable may be due to differences in expectations to future returns in pulse and conventional fishing.

For all the models, we have also tried to use non-pulse related investments instead of total investments including pulse related investments as a dependent variable. In all these estimations, the pulse dummy turns out to be insignificant, which indicates that vessels conducting pulse fishing may invest more because of the type of gear used. However, this issue must be further investigated, and therefore conducting empirical studies to investigate explanations for differences in investments between fleet segments is an important area for future research.

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