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# Exit and entry of fishing vessels: an evaluation of factors affecting investment decisions in the North Sea English beam trawl fleet

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A profitable fishery attracts additional effort (vessels enter), eventually leading to overcapacity and less profit. Similarly, fishing vessels exit depending on their economic viability (or reduced expectations of future benefits) or encouraged by schemes such as decommissioning grants and/or when there is consolidation of fishing effort within a tradable rights-based quota system (e.g. individual transferable quotas). The strategic decision-making behaviour of fishers in entering or exiting the English North Sea beam trawl fishery is analysed using a discrete choice model by integrating data on vessel characteristics with available cost data, decommissioning grant information, and other factors that potentially influence anticipated benefits or future risks. It is then possible to predict whether operators choose to enter, stay, exit, or decommission. Important factors affecting investment include vessel age and size, future revenues, operating costs (e.g. fuel), stock status of the main target species, and the impact of management measures (e.g. total allowable catches) and total fleet size (a proxy for congestion). Based on the results, the predicted marginal effects of each factor are presented and the impact of each is discussed in the context of policies developed to align fleet capacity with fishing opportunities.

**Keywords:** decision-making, discrete choice model, entry, exit, investment, linear models, overcapacity, random utility model, RUM, vpue.

## Introduction

Pioneering research in fisheries economics (Gordon, 1954; Scott, 1955) presented equilibrium models based on entering and exiting common property fisheries. Those authors argued that fishing effort would increase with the entry of new vessels as long as the fishery remained profitable. In contrast, as profits declined, vessels were assumed to exit the fishery if they could achieve greater returns on their capital investment elsewhere. These classic models assume that fishing effort and boats can move freely in and out of fisheries as a result of open access to a stock and to other stocks in other fisheries, or be used for other purposes than fishing. In the UK, however, fisheries are managed by a limited licensing system, thereby constraining the ability of individuals to move in and out of fisheries. Entry is restricted by the availability of licences or quotas, and exit is made more difficult because there is limited alternative use for the boat, which cannot be used in any other production process, so is not malleable (Clark *et al.*, 1979). There is extensive literature on the theoretical economics of entry–exit schemes within industrial organizations (e.g. Scherer and Ross, 1990), but very little empirical work. Most industry research that has considered the dynamic nature of a firm has concentrated on new entrants and views exit predominantly as a symbol of failure (Jovanovic, 1982; Hopenhayn, 1992; Jovanovic and MacDonald, 1994). Various authors have suggested that firms exit in two ways (Holmes and Schmitz, 1990; Agarwal and Gort, 1996; Dunne *et al.*, 2005; Plehn-Dujowich, 2009). First, a firm could terminate its operations and sell its assets at a salvage value, and second, it could exit its current business and reallocate the assets and know-how towards another line of business. Fishing firms, be they owner–operator or larger firms, behave in a similar way, but with greater uncertainty attributable to changing stock levels, management regulations, market prices, and fuel costs. Hence, the decisions of vessel operators to stay in, enter into, or exit from a fishery are influenced by a combination of economic and biological factors, as well as personal reasons.

In other studies on the North Sea flatfish fishery, Mardle *et al.* (2005, 2006) showed that vessel age, realized and expected revenues, and the status of the main target species had a bearing on the decision for a vessel to participate in a fishery. We extend these analyses, providing additional data on the rates of decommissioning and the costs of fishing, by including fuel-price data and data on the catches of sole (*Solea solea*) and anglerfish (*Lophius* spp.) separately, in addition to the main target stock, plaice (*Pleuronectes platessa*). Apart from voluntary decommissioning schemes, the option to trade quota (with an individual transferable quota, ITQ, system in the Netherlands and a quasi-ITQ system in the UK, described below) provides the opportunity for fleet rationalization in this case study. Therefore, within the context of non-market and market means to reduce capacity, we evaluate here the choices available to fishers and their responses, either to

(i) stay in a fishery, (ii) exit, (iii) decommission, or (iv) join and enter the fishery. In both exit and decommission options, the vessel is assumed to leave the fishery, but for decommissioning, a premium is paid to the owner. Here, we discriminate between the two options to test whether different factors affect each uniquely.

Under the Common Fishery Policy of the EU, each Member State has a fixed proportion of a species quota, referred to as relative stability (based on that country's historical access rights) and, apart from minor deviations from the rule, each boat in the UK has quota which is a proportion of the country's share (European Commission, 1996, 1997, 1999). Also in the UK, a quasi-ITQ system exists where quota entitlements and their trade are administered (or at the very least recorded) by Producer Organizations (POs), but the government has never endorsed a system of fully tradable harvest rights. Before 1999, the English fleet was managed by licence and quota restrictions, where quotas could be transferred to other fishing vessels within the POs. Quota could be leased but not permanently traded, although occasionally the government allowed once-off permanent trades (within and across POs) to rid the system of all leasing arrangements that had become permanent. Post-1999, quotas were allocated directly to vessels, as a fixed quota allocation (FQA). While being a fixed nominal amount of quota rather than a proportion of the total country total allowable catch (TAC), FQAs could be traded by individuals on a permanent basis or leased annually. Compared with the management arrangements in the UK, flatfish fisheries in the Netherlands before the 1990s were managed on an individual quota (IQ) system, whereby IQs could not be sold permanently or leased because it was suggested that quotas would be concentrated in an undesirable way (Smit, 2001). In the early 1990s, a new policy was adopted, with groups of vessels operating within a PO framework given full quota management responsibilities. The fishers within those groups pooled their ITQs and days at sea, allowing the PO board to control the transfer of ITQs and days at sea on a permanent basis (van Hoof, 2010).

In the UK, apart from management via quotas, as just described, a system of vessel capacity units (VCUs), based on size and engine power, was implemented to administer fishing capacity. Attempts were made in the 1980s, 1990s, and 2002 to reduce fishing capacity and effort through multiannual guidance programmes (MAGPs), with many countries including the UK implementing decommissioning schemes (European Court of Auditors, 1994, 1997). The MAGPs were funded by various financial instruments. This funding significantly reduced vessel numbers in the UK, decommissioning 225 vessels between 1984 and 1986, under MAGP I (Pascoe *et al.*, 2002). Then, between 1987 and 1991 under MAGP II, another 686 vessels were decommissioned to cut engine power tonnage and effort. MAGP III, introduced in 1992, ran for 5 years and resulted in the removal of another 578 vessels. Then, from 1997 to 2002 under MAGP IV, another ~170 boats were decommissioned based on fleet segment and the extent of overexploitation of targeted stocks. Capacity control since the end of MAGP IV has been replaced by effort ceilings, controlled by rules for entry and exit. Simply, a vessel can only enter a fishery when the equivalent capacity has exited. Decommissioning tended to result in older, less-efficient boats being removed, creating a modern, efficient fleet, essentially failing to reduce capacity and hence reduce fishing mortality, especially with the quota for decommissioned vessels making its way back into the pool of quota entitlements that were traded and/or leased.

Here, we assume that investment (or disinvestment) decisions are related primarily to actual or expected profits and the availability of decommissioning schemes. However, because the computation of individual profits requires detailed cost data, which is difficult to obtain and often confidential, revenues are utilized as a proxy for economic viability. Pradhan and Leung (2004) used revenue by gross tonnage within a multinomial logit framework to model exit and entry strategies of Hawaiian longliners. Given the value of information in their results, and using a random utility framework provided by McFadden (1974), we accommodate a multinomial logit model (unordered) and evaluate the probability of vessels to enter, stay, exit, or decommission from the English North Sea beam trawl fleet. This information is used to evaluate potential alternative management strategies, and significant factors influencing investment are discussed in the context of policies developed to align fleet capacity with fishing opportunities.

## The English North Sea beam trawl fleet

In the North Sea, English vessels that target flatfish have traditionally caught plaice in a directed beam trawl fishery using 120 mm mesh north of 56°N (Figure 1), and in a mixed fishery targeting sole, using 80 mm mesh in the southern North Sea. In 2006, international landings of plaice in the North Sea amounted to 57 943 t, well below the peak of 170 000 t in 1989. Some 40% of the total international landings of plaice were reported by Dutch vessels. The UK accounted for 23% of the plaice landings, Denmark for 20% of the landings, and Belgium, Germany, France, and other countries for the remaining 17% of the total landings. Of international sole landings in 2006 (12 600 t), 71% were made by the Netherlands, 8% by Belgium, and the balance of 21% by France, Germany, the UK, and Denmark. Sole landings by beam trawlers

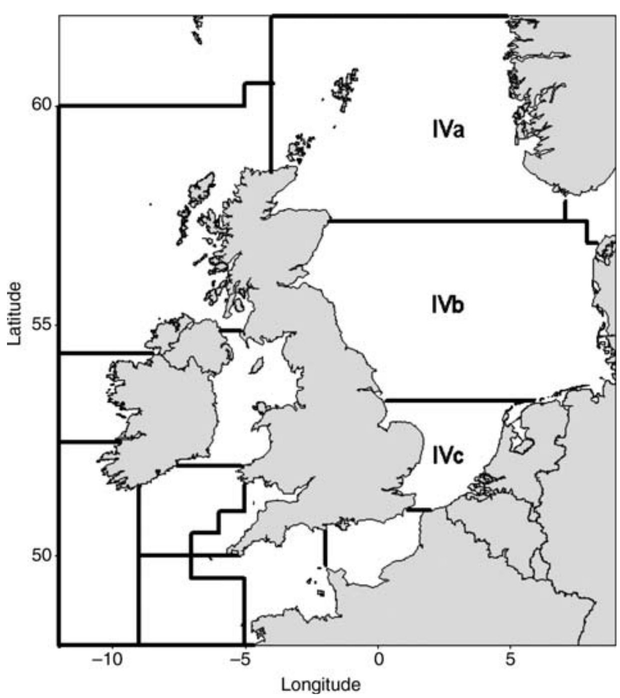


**Figure 1.** The study area (ICES Divisions IVb and IVc).

in the early 1990s were dominated by two good year classes and yielded ~32 000 t in total. The combined 2006 total first sale value of these two flatfish species was estimated at ~€350 million, of which €140 million was from plaice sales. The English beam trawl fleet expanded in the early 1990s, through investment in newer trawlers and an expansion of the beam trawl fleet in English east coast ports. From the mid-1990s, fleet size dropped, either as a consequence of older vessels leaving the fishery or declines in the value per unit effort (vpue) of plaice at the same time, or both. Exploitation rates of plaice and sole in the North Sea (Figure 2) clearly follow the trend in the number of vessels in the fleet (Figure 3). Between 2000 and 2005, increases in the fuel price (31.1%) reduced the viability of many fishing operations. Beam trawling is fuel-intensive because heavy gear is dragged relatively fast over the seabed. Until 2003, the English North Sea beam trawl fleet operated mainly out of English east coast ports in ICES Division IVb&c, typically spending an average of 250 days at sea annually on 6-d trips (Hutton *et al.*, 2004). Towards the end of 2002, an English east coast beam trawl company ceased fishing as fishing became unprofitable, claiming that it was not economically viable to catch fish for which they had a quota entitlement, that prices were poor, and that fuel costs were burgeoning as vessels had to operate far from port, near the Norwegian sector, to catch their quota (Hansard, 2002). At this time, the company operated eight vessels (down from 12 a few years earlier). Subsequently, the vessels were first leased then sold to Dutch operators, but they retained their English flag and quota entitlement. The relocation of many of the larger beam trawlers to Dutch ports provided an opportunity for rationalization as quota allocations for two or more vessels were transferred to newer fishing vessels by Dutch firms.

When fishing out of English ports, English beam trawlers generally chose to target both plaice and sole, but in recent years, Dutch skippers increasingly targeted sole because of its greater commercial value and the proximity of the sole fishing grounds in the southern North Sea, generally ICES Division IVc (Figure 1), to ports in the southern Netherlands. This change in tactical behaviour is evident in Figure 2, where from 2002 on, there is an increase in the exploitation rate for sole. We postulate that Dutch skippers acquired additional quota to fish for sole, but we do not have data on individual vessel quota entitlements to provide evidence of this transfer. A summary of physical vessel characteristics (over the period 1989–2007) is presented in Figure 3. The number of vessels within the fleet in a given year varies considerably. In 1993, for example, there were 152 vessels, but by 2007 just 29 remained, a considerable reduction in fleet size over just 15 years. From the summary statistics, it is apparent that there has been a slight increase in average vessel age, implying that as the number of vessels decreased, few newer vessels entered the fishery. Also noticeable from the fleet statistics is that the average vessel power, tonnage, VCUs, and length all increased slightly, suggesting that less powerful, smaller vessels left the fleet. Over this period too, beam trawlers were purchased originally from the Dutch, operated out of English ports for a while, before being purchased back again by the Dutch from the English. Also, some fishing vessels were occasionally tied up in ports in the Netherlands for more than a year at a time, awaiting engine refits. Observed decisions for English North Sea beam trawlers to exit, enter, decommission, or stay for the period 1989–2007 are presented in Figure 4. By 2007, the fleet consisted of 29 vessels that were part of the stay group, with four entering, compared with a peak of 152 in 1993, of which 32 entered, 19 exited, 88 stayed, and 13 left through a decommissioning scheme.

## Material and methods

The UK Department for the Environment, Food and Rural Affairs (Defra) database for fishing activity and the fleet register were used to select commercial landing and vessel data of English (and Welsh) beam trawl fleets operating in ICES Divisions IVb and IVc from 1989 to 2007, for input into the model. The fleet register contains information on vessel characteristics such as gross registered tonnage, grt, vessel length, and date of registration. We defined the beam trawl fleet based on the Data Collection Regulation (DCR) of the European Commission (EC, 2006), and from 2009 under a new regulation, the Data Collection Framework (DCF; EC, 2008). The DCR and the DCF define the beam trawl fleet according to its use of beam trawl gear for >50% of each trip. The study used information on vessels ≥10 m.

The specific beam trawl fleet activity or métier is defined as the fisher's tactic at a trip level, which is based on the group of targeted species. Métiers are characterized as an outcome of a trip based on the landing composition, assuming that what is landed in port is a reflection of what was originally targeted. Here, just demersal fish

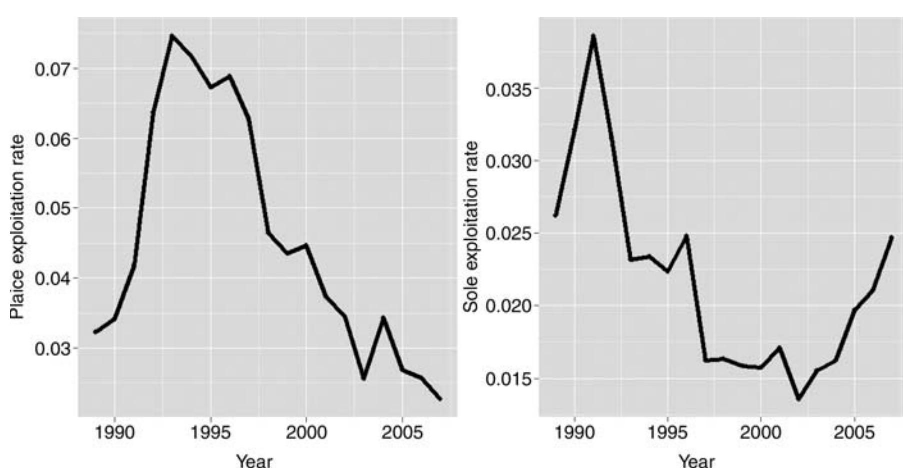


**Figure 2.** Exploitation rates (landings of the North Sea English beam trawl fleet, divided by SSB) for plaice (left) and sole (right).

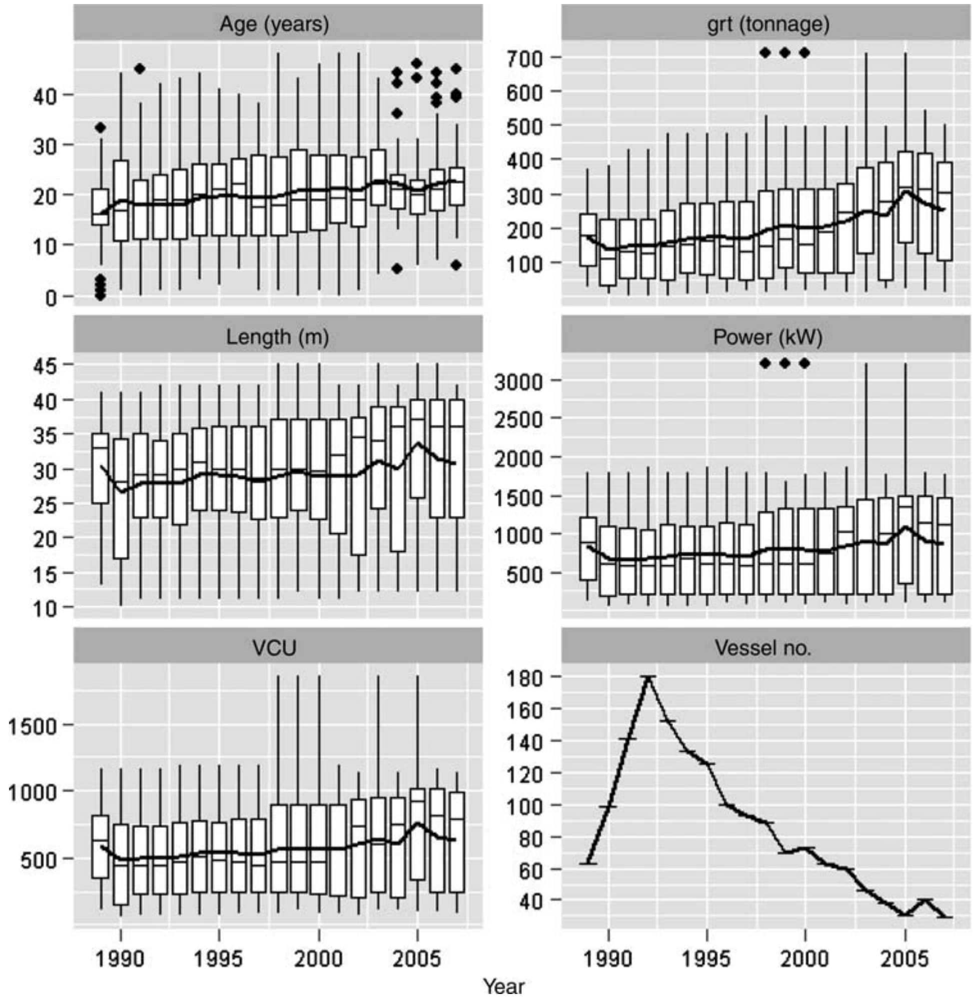


**Figure 3.** Box and whisker plots of vessel characteristics over the study period, the line representing the mean, the horizontal bar the 50th percentile, the top of the box the 75th percentile, and the base of the box the 25th percentile. Whiskers represent the range of data, and the solid diamonds are outliers.

métiers are analysed, by analysing the statistics from beam trawl gear used to target brown shrimp. The landing composition is calculated as a fraction of the total monetary catch, removing differences in catch rates attributable to vessel capacity. Moreover, fractions of the catches are based on the economic value, rather than weight, so reflecting the perception that fishers are profit-maximizers, in that uncommon but valuable species being targeted are given more weight in the analysis.

Decommissioning cost data were acquired from Defra for the years where decommissioning grants were offered (1991–2002). Based on data on grant offers and vessel tonnage, Figure 5 is the output from a linear model that predicts the premium that would have been offered based on vessel tonnage. The UK addressed MAGP requirements to reduce capacity and effort to meet with specific segment targets. It did not, however, identify overfished stocks or specific fleet segments where capacity needed to be reduced (Cappell *et al.*, 2010). As an example, the 1993–1998 decommissioning scheme was aimed at vessels more than 10 m long and 10+ years old, which had been at sea for a minimum of 100 d during each of the calendar years 1992 and 1993 (NIAO, 2006). Written applications from vessel owners stating the bid they would require for them to part with their vessels were requested, and these bids were ranked nationally based on the lowest cost per VCU. Over the years as the scheme progressed, the average bids increased as a result of collusion among vessel owners. For instance, the average successful bid in the UK scheme increased progressively from £349 per VCU in 1992 and 1993 to £758 per VCU in 1997 and 1998. The level of UK bids in 1997/1998 was significantly more than the average EU bid of £650 per VCU (NIAO, 2006). For 1993–1996, the schemes attracted 331, 431, 203, and 255 eligible applications annually, respectively, and the numbers decommissioned were 13 (in 1993), 6 (1994), 7 (1995), 2 (2001), and 4 (2002), a total of 32 beam trawlers. Most of the grant take-up was based on the decisions of the applicants, who were required to satisfy a number of qualification conditions, e.g. based on a minimum number of days at sea and vessel age. The target for this fleet segment was a 15% reduction in fishing capacity. That target was not met, however, possibly indicating that vessel owners had either made a decommissioning bid below the market rate or that they valued both licences and track record as higher than the value of decommissioning. Using recent decommissioning data, we assume that a vessel would have a grant uptake of 100% if successful. In terms of fuel costs, marine diesel prices

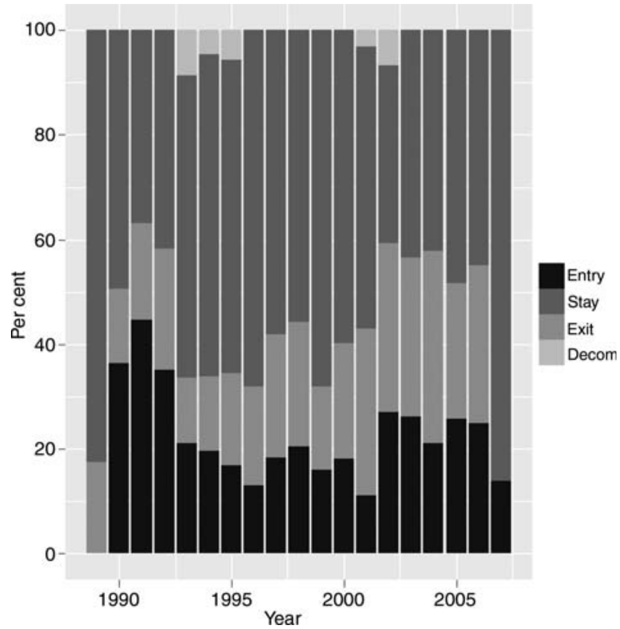


**Figure 4.** Exit, enter, stay, and decommission decisions observed in the study fishery over the period 1989–2007.

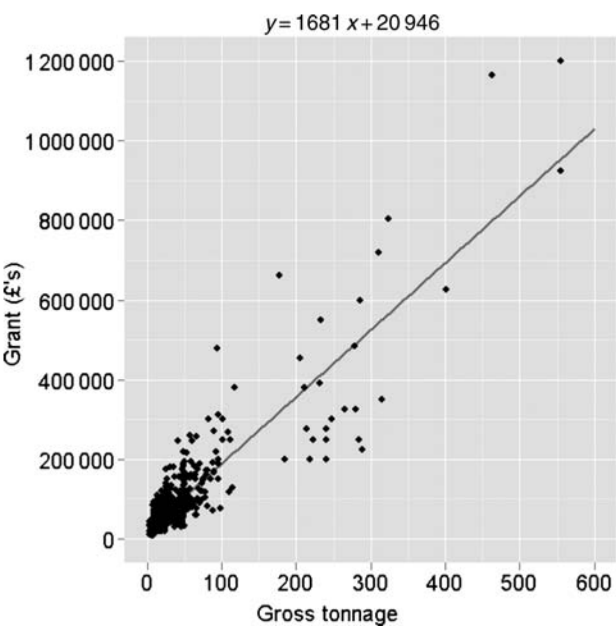


**Figure 5.** North Sea decommissioning grants offered plotted against vessel gross tonnage. Dots are the observations and the line the linear regression.

excluding value-added tax (VAT) and duty were obtained from the Department of Energy and Climate Change (DECC) and are presented in Figure 6. Most noticeable is the steady increase from 2002 compared with the relatively stable prices during the 1990s.

## Model description

Over the past few years, considerable attention has been applied to predicting fisher choices, particularly those concerning fishing location, by applying random utility methodology and models

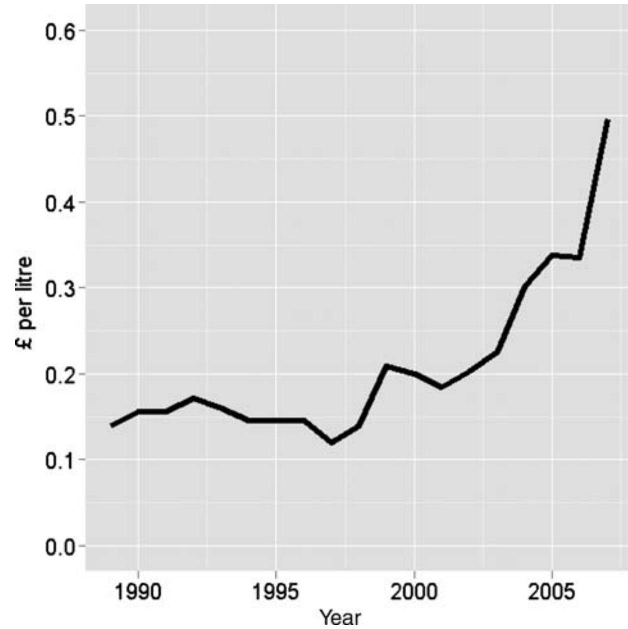


**Figure 6.** Average marine fuel prices (£ per litre, excluding VAT and duty). Source: DECC (UK Department of Energy and Climate Change).

(Bockstael and Opaluch, 1983; Eales and Wilen, 1986; Holland and Sutinen, 1999; Wilen *et al.*, 2002; Hutton *et al.*, 2004). The key characteristics of random utility models (RUMs) are that they model discrete decisions and can be described as follows. A decision-maker is faced with making a choice among a number of alternative options, obtaining differing levels of utility from each alternative option, and tending to choose one that maximizes utility. As such, and like other economics-based choice models, utility influences individual choice with a deterministic and stochastic error component.

For the most general form of the conditional logit choice model (McFadden, 1974, 1981), a set of unordered choices is assumed, and this can be written as

$$U_{ij} = \beta_{ij} z_{ij} + \varepsilon_{ij}, \quad (1)$$

where $U$ is the utility, $i$ the individual, $j$ the choice (such as a fishing trip), $z_{ij}$ attributes of choice $[x_{ij}\ w_i]$, where $x_{ij}$ are attributes of choice $j$ of individual $i$ and $w_i$ are attributes of individual $i$, $\varepsilon_{ij}$ the stochastic error component, which is random, and $\beta_{ij}$ a coefficient. It is assumed that the values of $\varepsilon_{ij}$ are independent across the different choices. This assumption implies a condition known as independence of irrelevant alternatives, which itself implies that providing other choices or changing the characteristics of a third choice does not affect the relative odds between the two choices considered. The probability of a given choice being made can be estimated from the utility derived. The multinomial logit model, Equation (2), used in this study differs from the conditional logit choice, Equation (1), in that only the characteristics of the individual ($w_i$) are included:

$$U_{ij} = \beta_j w_i + \varepsilon_{ij}. \quad (2)$$

The probability that an individual $i$ makes choice $j$ is then

$$\mathrm{Prob}(\gamma_i = j) = \frac{\exp(w_i\beta_j)}{\sum_{j=1}^{J}\exp(w_i\beta_j)}, \qquad (3)$$

where $\gamma_i$ is an indicator variable (with the same length as vector $J$) referring to the choice ($j$) made by individual $i$. SAS 9.0 software was used in the model estimation (logistic procedure; SAS Institute Inc., 1999).

The key independent response variables (Table 1) in the model include vessel age in years, because it is assumed that older vessels may exit because of higher costs of maintenance and operation and that newer vessels will enter. Fisher skills, knowledge, and experience are expected to relate to the annual revenues of the target species of the fleet, specifically plaice, anglerfish, and sole. Fishers are assumed to be profit maximizers, and it is expected that fishers with high revenues are more likely to stay in the fishery, whereas those with lower incomes are more likely to exit to seek other opportunities in alternative fisheries or industries. It is important to note that higher revenues for a vessel might not mean greater profit because costs vary considerably between operators. In keeping with the thesis of Mardle *et al.* (2005), we assume that the performance based on the total revenue of the species caught by a vessel in its first year of entry to the fishery meets the expectations of the decision unit, because they expect on entry to perform as well the rest of the fleet. Pradhan and Leung (2004) assume that a vessel's performance in its first year is equivalent to its previous year's performance elsewhere. For the English beam trawl fleet, we cannot assume this, however, because of the different target species and quota limitations elsewhere. For those already in the fishery, we assume that the decision to exit, to stay, or to decommission is based on the previous year's performance. The decision to enter a fishery may also be based on poor performance in another fishery, with the fisher perhaps seeking a better investment opportunity.

The variable decommissioning grant offered is included in the model to evaluate the effects of a fisher's decision to accept a grant to have their vessel removed permanently from the fishery. It is anticipated that a fisher will accept the grant if it is considerably more profitable to do so than to remain in the fishery. The model assumes that vessels have open access to the fishery, i.e. that they purchase a vessel and the licence with the entitlement to fish, but in reality the total number of UK beam trawlers is restricted. Congestion and overcrowding effects are investigated by the inclusion of the number of vessels operating within a given year in the fishery as a variable (Bockstael and Opaluch, 1983; Ward and Sutinen, 1994).

The price per litre of subsidized marine diesel (excluding VAT and duty) was considered a key variable for inclusion, because higher fuel costs could reduce profit directly and lead to a decision to exit the fleet, especially if the value of the catch does not increase to compensate for the higher fuel cost. Alternatively, if fuel costs decrease, then the expectation would be that more vessels would enter the fishery. The fuel cost variable was lagged (i.e. $t+1$, where $t$ is year), because it was assumed that fishers would not enter or exit the fishery immediately in response to a change in fuel price, but rather as a strategic decision based on the average annual costs in the previous season.

Plaice was considered to be the main target species of the English fleet, so the spawning-stock biomass (SSB) of plaice was included as a variable in the model. As stock assessments use the previous year's catch to predict the next year's quota, this variable was lagged ($t+1$). It is assumed that a fisher would be likely to leave the fishery if past SSB was low. Conversely, if stock levels increase, then the assumption is that more vessels will enter the fishery.

**Table 1.** The explanatory variables used in the model.

| Variable | Description |
|---|---|
| 1 | Vessel age (years) |
| 2 | Annual individual plaice revenue (£) |
| 3 | Individual decommissioning grant offered (£) |
| 4 | Annual fleet size in numbers |
| 5 | Lagged SSB of plaice (t) |
| 6 | Annual individual anglerfish revenue (£) |
| 7 | Lagged average annual fuel price (£) |
| 8 | Annual individual sole revenue (£) |
| 9 | Individual vessel length (m) |

**Table 2.** Type 3 analysis of effects, showing the overall significance of each variable retained in the final model, using Wald $\chi^2$ statistics and given that the other variables are in the model.

| Variable | d.f. | Wald $\chi^2$ | Pr > $\chi^2$ |
|---|---|---|---|
| 1 | 3 | 21.2413 | <0.0001 |
| 2 | 3 | 44.991 | <0.0001 |
| 3 | 3 | 20.1455 | 0.0002 |
| 4 | 3 | 18.7338 | 0.0003 |
| 5 | 3 | 10.2478 | 0.0166 |
| 6 | 3 | 9.6155 | 0.0221 |
| 7 | 3 | 10.2033 | 0.0169 |
| 8 | 3 | 8.4166 | 0.0381 |
| 9 | 3 | 15.5148 | 0.0014 |

Overall, vessel length (m) was included as a variable to determine whether being within any particular vessel-length group influenced a fishers' decision to enter, stay, or exit. Vessel size is correlated with capital invested and may affect a fisher's decision. Smaller vessels have fewer decisions on where to fish, because they are restricted primarily to inshore fishing grounds, but should have lower fuel costs. By comparison, medium-sized or large vessels can operate farther offshore for longer, so have more variable fishing opportunities.

Other variables initially included in the models were removed because the observation was made that they were not significant. These included cod (*Gadus morhua*) revenue, the SSB of sole, total revenue, VCU, grt, engine power (kW), turbot (*Psetta maxima*) revenue, and the monetary sum of other landings (excluding plaice, sole, turbot, anglerfish, and cod).

## Results

The results for the multinomial logit model (unordered) are given in Tables 2 and 3. The coefficients are interpretable in terms of the direction of the influence of a variable on the utility, and the probability of entering, exiting, staying, or decommissioning vs. staying (Table 3). Only variables with significance levels of $p < 0.05$ were included in the models with respect to the type 3 analyses of effects (Table 2), which shows the overall significance of each variable retained in the final model, using the Wald Chi-squared statistics. The model is highly significant and has a likelihood ratio $\chi^2$, 27 d.f., of 393.8138, $p < 0.0001$, and a value of $r^2$ of 0.22, where $n = 1595$.

**Table 3.** Parameter estimates from the multinomial logit model.

| Variable | Entry | Exit | Decommission |
|---|---|---|---|
| Intercept | −1.33** | +0.06 | −7.31*** |
| Vessel age in years | −1.70e−02** | −5.78e−03 | +6.65e−02*** |
| Annual individual plaice revenue (£) | −4.49e−06*** | −4.79e−06*** | +5.72e−06** |
| Individual decommissioning grant offered (£) | −9.19e−07* | −2.74e−07 | +6.87e−06*** |
| Annual fleet size in numbers | +4.04e−03** | −1.82e−03 | +2.97e−02*** |
| Lagged SSB of plaice (t) | +3.14e−06** | +2.85e−07 | −6.46e−06 |
| Annual individual anglerfish revenue (£) | −1.00e−05** | −1.00e−05** | −3.00e−05 |
| Lagged average annual fuel price (£) | +4.31e−02** | +1.10e−02 | +1.88e−01** |
| Annual individual sole revenue (£) | −1.21e−06 | +5.64e−06 | −5.00e−05** |
| Individual vessel length (m) | −1.88e−02 | −2.57e−02** | −1.24e−01*** |

*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

The results for the variable vessel age indicate, as expected, that older vessels are more likely to leave the fishery. Essentially, older vessels are replaced by newer ones, resulting in an increase in the efficiency of the fleet. Hutton *et al.* (2008) considered the implications of older vessels leaving the fleet and the resulting changes in technical efficiency of the fleet remaining. Our results suggest that the bigger the fleet, the more vessels that enter, and the smaller the fleet, the greater the odds of vessels exiting. Historically, the trends reflect an expansion of the fleet as fishing opportunities increase (large catches of plaice and high revenues), resulting in more vessels entering the fishery. Fishers tend to follow others into a profitable fishery, so enter an ever-growing fleet. In recent years, the few newer and larger vessels remained active, acquiring newly available quota from vessels that exited the fleet. The coefficient for decommissioning suggests that the odds on a younger vessel in the fishery taking up a decommissioning scheme are low. Alternatively, older vessels were more likely to take up a decommissioning offer. Similarly significant was fleet size, because the bigger the fleet, the greater the odds of decommissioning. This result is intuitive, because the fleet size when it was at its largest coincided with the decommissioning schemes under MAGP III.

The stock status of plaice also had an important influence; the odds on entering the fishery increased when plaice stock levels were high. As anticipated, the results for plaice revenue indicated that vessels with lower revenues would have greater odds on exiting the fleet. The implication of vessels with low revenues (or low vpue) departing the fisheries is also likely to affect the overall efficiency of the fleet. A highly significant negative coefficient on the variable plaice revenue for entry is not intuitive, but the explanation for this may be that cost factors such as high fuel costs dominated during this period. Decommissioning programmes during the period of study did show the signs of enticing beam trawlers to decommission.

The positive significant coefficient for fuel prices for vessels entering suggested that the vessels would enter at lower costs of subsidized fuel. However, the choice to exit was not significant, possibly because of the relatively stable fuel prices throughout the 1990s. The significant coefficient for decommissioning suggests that when fuel prices were at their highest and a decommissioning scheme was available, fishers were likely to accept a grant to exit the fishery.

All the estimated parameters for vessel length were significant. The options all possess negative coefficients and suggest that smaller vessels were more likely to exit, enter, and decommission from the fleet. With lower capital cost outlays, smaller vessels tend to be more mobile in their movement in and out of fisheries. The effect of vessel size is also related to the variable decommissioning grant, which understandably has insignificant coefficients for exit, and a highly significant small coefficient for the decision to decommission. Fishers on the large most-modern vessels would have to be offered a good financial incentive to leave the fishery, fitting in with the observation that smaller vessels accepted the scheme offered. Of interest were the significant parameter estimates for anglerfish, showing similar trends for exit and entry as the revenue estimates for plaice. However, sole revenue provided a different set of trends, notably the insignificant variables for entry and exit, which suggests that it was not of great importance to fisher decision-making in terms of whether to enter or exit the fishery.

## Discussion

A decision to enter or exit a fishery depends on the expected benefits, which include future revenue, the stock status of the main target species, and crowding effects (the number of vessels in the fleet). Operators also make decisions based on age of the vessel. Here, the results indicate this to be the case for English North Sea beam trawlers. Management measures (TACs and effort limitations) which impact on revenues also affect future stock levels, because a TAC is based on the proportion of mature fish that can be harvested from a stock. Therefore, if SSB falls by a set amount, this will be transferred to revenue and impact the proportion of vessels that enter or exit the fleet.

To illustrate the marginal effects of each significant explanatory variable, the mean model coefficients from Table 3 were kept constant, and the predicted probability of exit, entry, and decommission were computed over a range for each explanatory variable. The outcomes of the simulations are shown in Figure 7.

In general, the outcomes are as expected and can be simply summarized as follows. Figure 7a supports the notion that an older vessel is less likely to enter a fishery than a newer vessel; decommissioning and exit probabilities increase with age. These predictions are plausible given the decommissioning schemes under the MAGP programmes of the 1990s. Figure 7b shows that smaller vessels have a higher probability of taking up a decommissioning scheme, consistent with the general patterns witnessed under the MAGPs. The decision by the owners of such vessels to decommission may also suggest that the owners of smaller vessels find it easier to part with a vessel than stakeholders

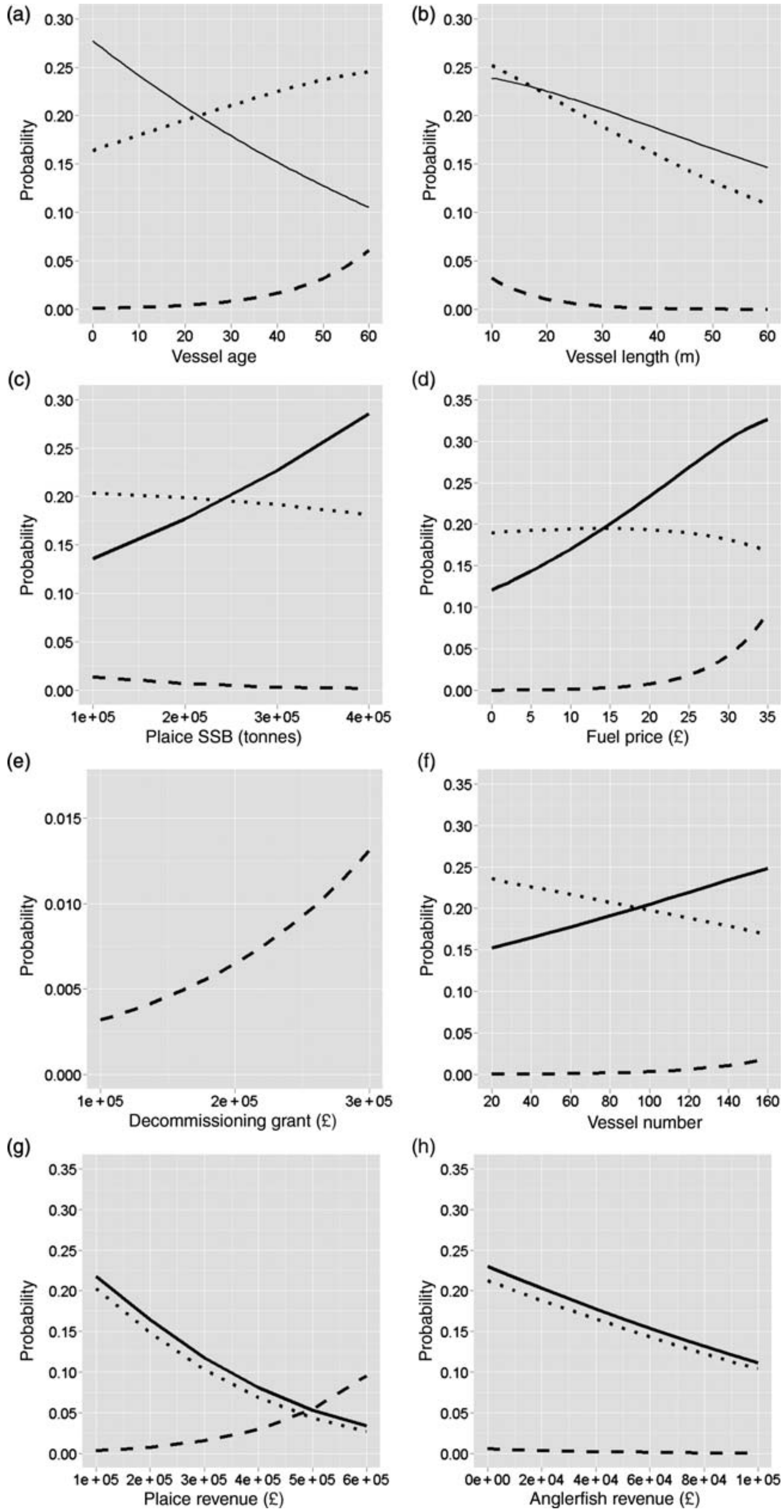


**Figure 7.** Simulations of the probability of exit, entry, and decommissioning decisions, i.e. 1 minus each probability equals the probability of staying in the fishery. The solid lines represent the probability of entry vs. stay, the dotted lines the probability of exit vs. stay, and the dashed lines the probability of decommissioning vs. stay. (a) Vessel age, (b) vessel length, (c) plaice SSB, (d) fuel price, (e) decommissioning grant, (f) number of vessels, (g) plaice revenue, (h) anglerfish revenue.

investing in bigger boats, where a group decision is required within a firm, and where financial considerations are more important. Figure 7c shows that with an increase in stock size of mature fish (SSB), it is more attractive for vessels to enter; on the other hand, the probability of exit is reasonably constant. However, it does seem that vessels are less likely to exit at lower levels of SSB, suggesting that the fishery is profitable at reduced plaice SSB and that the fleet switches to targeting other demersal species such as sole, anglerfish, cod, or turbot or mixed combinations of these species. Figure 7d shows that fuel prices are important; in 2001, they accounted for 70% of running costs in the beam trawl fishery (Mardle *et al.*, 2005). At low and increasing costs, a vessel is more likely to enter until it appears to level off at £0.35 per litre of fuel. The simulation also shows that, with an increase in fuel price, fishers are more likely to decommission their vessels. These are possibly the result of vessels being older and inefficient, and hence more costly to run. This highlights the importance of fuel costs and the potential effects of fuel subsidies. Fuel subsidies have a direct effect on fishing effort (Sumaila *et al.*, 2006). They are controversial, because they encourage wasteful, uneconomic fishing practices in already overcapitalized fisheries, and they maintain fishing effort even when stock levels decline. Figure 7e shows that the beam trawl flatfish fishery is of great value to fishers and that a grant of £300 000 would only entice 1.3% of beam trawl fishers to decommission their vessel. The policy implications are that, given the overcapacity in the North Sea and the declining stocks, it is costly for a decommissioning scheme to become the most effective method of reducing capacity. Decommissioning is said to be only a short-term incentive for solving the underlying overcapacity issue, although some advocate that it is the only solution; however, it cannot solve the inherent incentive problem of over-investment and effort creep (Weninger and McConnell, 2000). In the longer term, therefore, one would expect a similar capacity/effort imbalance after a decommissioning scheme. Alternatively, if market forces dominate under a tradable quota system, the fleet will rationalize within a system of ITQs, where the race for fish is removed, allowing individuals to catch a set quantity and allowing investment and production strategies to be internally driven by market forces. As quotas decrease and fuel prices rise, fishing vessels may be forced to tie up and be sold, or to exit the fishery to operate in areas away from the North Sea (for most of the period of the study, beam trawl licences permitted fishing in other areas and quotas were not gear-specific). Redistributing overcapacity elsewhere or tying up, however, could cause social and economic problems to coastal communities that rely on the fishery for employment. In fact, the quasi-ITQ system in the UK (and the ITQ system in the Netherlands) has resulted in just that, a smaller English North Sea beam trawl fleet (now operated mainly by Dutch skippers) with traditional North Sea English fishing ports in decline.

The results in Figure 7f demonstrate that the probability of entering the fishery increases with fleet size. However, Dasgupta and Heal (1979) state that ever-increasing numbers of competing fishers lead to externalities between them, i.e. the more one catches, the less is available to others, so that each operator believes that none of its competitors will adhere to a future conservation policy and in turn sees no benefit to pursue it personally. As fleet size expands, average landings and revenues per vessel decline along with catch per unit effort (cpue), the costs of fishing effort increase, and resource rents dissipate (Ward and Sutinen, 1994). Anecdotal information suggests that the fishery addressed here did just that, in that it expanded as plaice catch rates were high, followed by success that was short-lived as catch rates declined and fuel costs rose, and with the demise of the fishery reflected by dissipating profits.

Figure 7g and h shows similar trends for both exit and entry, in that the less the revenue of plaice and anglerfish, the greater the probability of entry and exit (the results for sole are not shown). As noted above, cost factors (e.g. fuel costs) may have dominated during this period. In addition, plaice catches and revenue were relatively stable compared with such other covariates as fuel costs, which could adversely dominate in their explanatory power. The implications of a smaller fleet on fish stocks are yet to be evaluated. One method to explore the effects of alternative fleet management policies on fish stocks is management strategy evaluation (MSE; De Oliveira *et al.*, 2008). Under an MSE approach, the objective is to evaluate the management consequences of a strategy under alternative assumptions about stock dynamics, i.e. its robustness to uncertainty. A key element is to identify the relative impact of particular assumptions about the resource (e.g. stock–recruitment relationship, natural mortality) or fleet dynamics (e.g. the implementation of management regulations). The overall objective of fishery management is balancing the short- and the long-term socio-economic needs of stakeholders while maintaining a healthy stock and ultimately rebuilding fisheries.

To conclude, we have discussed the implementation of a discrete choice model (specified as a RUM) in an attempt to explore and better understand English beam trawl fisher long-term investment behaviour. The results confirm the notion that vessel age, vessel length, stock status (plaice SSB), fuel cost, the availability of decommissioning grants, fleet size, and the revenues from target species are significant factors in determining fisher decision-making. The low model $r^2$ of 0.22 suggests that other factors not incorporated in the model play a role, e.g. the real economic viability of each vessel (knowledge of which is limited by the limited availability of cost-structure data), their ownership, and the investment portfolio of firms that own single and multiple vessels, as well as factors such as skipper skill and age, and/or the availability of a skilled crew. The model predictions were similar to the actual choices apart from the decision to decommission, possibly because relatively few beam trawlers took up the decommissioning schemes offered during the period investigated. The UK decommissioning schemes were *ad hoc* in nature and spread across many sectors, not just the beam trawl fleet. Rather, it was a case where some owners took the advantage of limited decommissioning grants when they were worst off financially (with low catch rates of plaice and high fuel costs), whereas others valued future catches, the value of the licence, and their capital investment higher than the value of decommissioning.

Future studies should, if feasible, include an investigation of other externalities than subsidies on fuel and decommissioning grants. Subsidies could include tax relief in the form of income support and unemployment insurance, capital support such as for vessel modernization (a new engine refit), minimum price, and processing and marketing subsidies. Such financial instruments could help in attaining profitability and influence future investment decisions by a fisher. In addition, it would be of interest to know whether the skippers who decommissioned reinvested in newer vessels, encouraged by the profits of the fishery. Regulations, policy and alternative fishery performance, pre-enter and post-exit revenues, and costs, if available, would further enrich such analyses. Overall, our analysis has provided greater insight into the use of econometric RUMs in interpreting fisher behaviour.

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