Barcelona School of Economics

Master's Degree in Economics

Brexfish:

A Discrete Choice Model of Fishing Vessel Landing Decisions

Pre- and Post-Brexit

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Abstract (English)

This paper investigates the impact of Brexit upon the British and European Union fishing industry, specifically analysing the effects of non-tariff barriers introduced by the Trade and Cooperation Agreement (TCA) on the landing decisions of UK and EU fishing vessels. Utilising a novel dataset and a mixed logit discrete choice model, the study reveals significant shifts in landing preferences post-Brexit, driven by increased costs and delays from new customs regulations. The findings show a notable reduction in EU vessels landing in the UK, that is translated into a 14% reduction of producer surplus of fishing companies, evidencing and quantifying the adverse economic effects of the introduction of Brexit-related non-tariff barriers.

Abstract (Spanish)

Este trabajo investiga el impacto del Brexit en la industria pesquera británica y de la Unión Europea, analizando específicamente los efectos de las barreras no arancelarias introducidas por el Acuerdo de Comercio y Cooperación (TCA) en las decisiones de desembarque de los barcos pesqueros del Reino Unido y de la UE. Utilizando una base de datos novedosa y un modelo logit mixto de elección discreta, el estudio revela cambios significativos en las preferencias de desembarque tras el Brexit, impulsados por el aumento de los costes y los retrasos derivados de la nueva normativa aduanera. Los resultados muestran una notable reducción de los barcos de la UE que desembarcan en el Reino Unido, que se traduce en una reducción del 14% del excedente de los productores de las empresas pesqueras, lo que evidencia y cuantifica los efectos económicos adversos de la introducción de barreras no arancelarias relacionadas con el Brexit.

Keywords (English)

- Brexit
- Non-tariff Barriers
- Discrete Choice Model
- International Trade
- Fishing Industry
- Geo-spatial Data

Keywords (Catalan/Spanish)

- Brexit
- Barreras no arancelarias
- Modelo de decisión
- Comercio Internacional
- Industria pesquera
- Datos geoespaciales

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1 Introduction

Brexit represents one of the most significant events in recent UK history, fundamentally altering the nation's trade, legislative frameworks, and economic interactions both domestically and internationally. As the UK officially left the EU on January 1st 2021, it instituted these changes through a Trade and Cooperation Agreement (TCA) that redefined a new commercial relationship with it's major trading partner.

The new regulatory changes particularly impacted the fishing industry, a sector that has been historically intertwined with European markets. In particular, the TCA brought forth a new set of non-tariff trade barriers, including comprehensive customs checks and documentation requirements, such as export health certificates or catch certificates. All these measures introduced important delays and additional costs, significantly affecting the profitability and operational efficiency of many fishing enterprises.

This master project examines the consequences of these non-tariff barriers on the fishing industry, focusing on how these regulatory changes influence the decision-making processes of UK and EU fishing vessels regarding their chosen port of landing. Therefore, we aim to determine whether the policy implementation in January 2021 led to shifts in landing preferences and overall industry dynamics.

To explore these dynamics, we build a comprehensive dataset that allows us to track individual boats and it's landing decisions over time. For this, we first select a relevant sample of fishing vessels, where we included UK and EU boats that had landed at least once in the UK or UK boats that had landed at least once in the EU before and after the implementation of the regulations. This selection aimed to identify the boats that were likely to be impacted by the new regulations.

To assess the effect of these barriers, we model each fishing boat landing decision though a random utility discrete-choice model. We first assume that boats act as rational agents seeking to maximise their own profit function, which is modelled through their utility function: boats choose to land in the countries where they get the highest utility for their capture. Then, we incorporate into the model the introduction of the non-tariff barriers as a constant fixed cost per landing for each affected boat (i.e. a EU boat landing in the UK or a UK boat landing in the EU).

Given the panel data structure of our dataset, which contains repeated landing choices of the same boats over time, we employ a mixed logit model. This allows us to account for individual heterogeneity and potential correlations of unobserved factors over time, as well as to relax the IIA assumption required by conventional multinomial logit models.

Therefore, this approach enables us to flexibly analyse how the introduction of the non-tariff barriers influenced landing choices, controlling for variables such as distance to the different options, prices at destination or boat-specific characteristics.

We find that the introduction of non-tariff barriers affected the landing decisions of EU boats in the UK, causing a displacement to nearby countries. However, the effect is not so clear for British boats. After this, with the retrieved coefficients from our model, we run a counterfactual model for EU boats where no barriers are introduced to estimate the change in producer surplus. We conclude that the disruptions related to barriers results in a 14% reduction of producer surplus for fishing companies.

The master thesis is structured as follow. Section 2 delves into the institutional details of the background of the fishing industry and Section 3 reviews related literature. Section 4 presents the data sources and sample selection methodology while Section 5 outlines the empirical strategy employed. Section 6 presents the empirical results and their implications. Finally, Section 7 concludes.

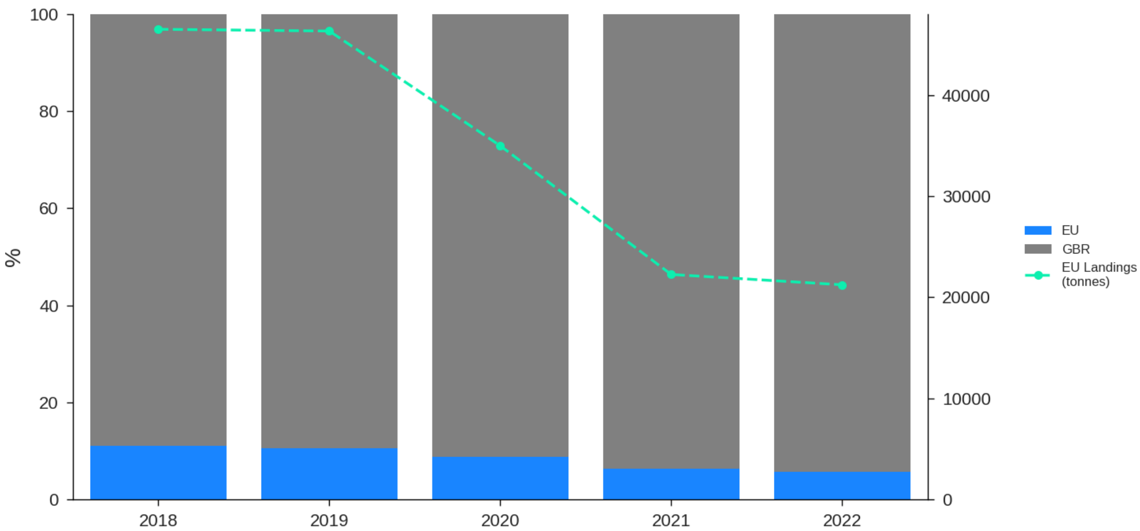
2 Institutional Background

On the 1st of January 2021, the UK introduced major regulatory changes though a Trade and Cooperation Agreement in a last minute negotiation days before the limit agreed date.[1]

The new regulatory changes particularly impacted the fishing industry, where one of the main disruption introduced were the non-tariff trade measures. Importantly, there were large implications from these non-tariff barriers. For example, the cost of health certificates, necessary for exporting fish to the EU, has quadrupled from £60 per day to £240 per day, significantly impacting profitability for many fishermen (Parkinson, 2023). Additionally, new customs checks and paperwork led to delays, reducing the freshness of fish and leading to lost customers (University of York, 2022).

After establishing what our objectives are, we proceeded to generate Figure 1, which looks at the change in share and total quantity of landings in tonnes for vessels fishing within the UK, depending upon their flag. Ultimately, the share of EU quantity of landings dramatically reduced in 2021, whilst the amount of total landings in tonnes started to reduce from 2019.

Figure 1: Landings Weight and Share by Region



This brings us onto exactly why the trade shock of Brexit is relevant to the fishing indus-

[1] In fact, the agreement was signed on the 24th of December of 2020, days before the limit deadline agreed with the EU to enter into force. This is and important feature of this new legislation package, since the fact that was decide last minute reduces (although only slightly) the anticipation concerns.

try. The UK heavily relies upon European trade within the fishing industry, with over 70 per cent of the UK's fish exports going to the EU in 2018 (Harkell, 2019). Additionally, EU access to waters was particularly pivotal for particular regions in the UK, with non-UK boats capturing over half of the fish and shellfish in Scottish waters (Johnson, 2016). Point being, ensuring smooth exit from the EU is critical in guaranteeing that the industry continues to grow.

However, this smooth exit was far from the case. After the TCA was enacted, UK seafood exports to the EU, the industry's largest market, have fallen by 83% (Whale, 2023). Meanwhile, preliminary economic estimates show a decline in the number of active fishing vessels and full-time fishing-related jobs, continuing a decade-long trend. From 2011 to 2021, the number of registered fishing vessels in the UK dropped by 10%, and the number of fishermen decreased by 1,700 (Whale, 2023). Thus, by the end of 2021, it became clear that the anticipated benefits were not materialising as promised, as in some cases, fishermen had to travel further and incur higher costs to catch the same amount of fish (Monk, 2024).

Thus, this forms our research question, of whether these non-tariff barriers effected the decision making process of fishing vessels, given that additional administrative costs, increased red tape, new checks and labor shortages may incentivise EU vessels avoid UK waters, and vice-versa for UK vessels.

3 Literature Review

In this section, we provide the most relevant connections between our master project and the existing body of literature.

A recent, growing body of literature discusses the role of transportation in trade using novel geospatial data, covering topics such as international trade, supply chain disruptions, and the impact of ports. Some relevant papers are Brancaccio et al. (2021), Kalouptsidi (2014), and Ducruet et al. (2021). Moreover Kalouptsidi and coauthors (2024) estimate the impact of disruptions on individual ports, finding significant effects in terms of costs and volatility. Our contribution to this body of literature is the study of the impact of disruptions (the policy change in our case) at the level of individual boats.

Secondly, our work is related to the literature investigating the impact of restrictions on the fishing industry. The main related work is by Natividad (2014), who studies the impact of the introduction of quotas on within-firm productivity and market prices. In contrast, our paper focuses on the individual decisions of each boat to observe how the restrictions affect them.

Thirdly, our work contributes crucially to the discussion regarding the impacts of Brexit on the economic conditions of the affected countries. Among the most recent contributions, Thissen et al. (2020) assess the impact of Brexit on regional competitiveness. We contribute by proving how Brexit resulted in a reduction in the competitiveness of the UK, as demonstrated by changes in the decisions of individual boats. Additionally, our results are consistent with theoretical results from Hosoe (2018), who predicts a total export loss of 5.1–5.8% of UK GDP. While we do not specifically estimate the impact on GDP, our contribution demonstrates the damage inflicted by non-tariff barriers on a sector of the British economy. [2]

Finally, our paper contributes to the literature concerning the impact of non-tariff barriers on welfare and trade. In particular, in recent studies, the impact of non-tariff barriers on trade has been extensively examined. For instance, Kinzius et al. (2022) explore the role of non-tariff barriers in trade protection. Additionally, Bakker et al. (2022) investigate the

[2] Policy considerations can be drawn from the following paper that discusses directly the issue for the fishing industry: Phillipson and Symes (2020).

effects of non-tariff barriers on consumer prices in the context of Brexit, they find a deadweight loss of approximately £1.06 billion. We find consistent results with the previous literature in our utility framework.

4 Data

4.1 Sources

4.1.1 Global Fishing Watch (GFW)

The Global Fishing Watch (GFW) geographical dataset is an extensive collection of data aimed at providing insights into global fishing activities. It combines tracking data from the publicly available Automatic Identification System (AIS) and information obtained from vessel monitoring systems (VMS) with machine learning algorithms to track the movement of fishing vessels across the worlds oceans.

The database contains both data on the identifiers of a vessel and some of its technical characteristics (e.g., flag, type of vessel, fishing gear used), as well as information on various events and their timestamp. These events can include fishing activities, port visits, and encounters with other vessels, among others. In this study, we will focus on port visits and fishing events.

To access the GFW database, it is necessary to do so through their free and public open API.[3] It is possible to make and send the queries through an R package powered by GFW.[4]

4.1.2 MMO landings and price data

The UK Marine Management Organisation is a non-departmental public body established in the United Kingdom. They provide a database that contains observations on every fishing boat landing to a UK port from 2013-2022. It records information on the price and weight of landing, capture characteristics (species type, zone of capture and if the capture is quota/non-quota), boat characteristics (nationality, gear type and length) and port of landing.

[3] API stands for application programming interface. An API allows a user to query a resource and retrieve and download data in a machine-readable format. You can create a simple query in the address bar in a web browser. However, a more complex query generally requires using a programming language. Commonly used languages for querying APIs are Python and R.

[4] https://globalfishingwatch.org/our-apis

4.1.3 EUMOFA price data

The European Market Observatory for fisheries and aquaculture products, dependent on the European Commission, provides data on prices of landed fish and seafood in all countries that belong to the European Union.

4.2 Sample

4.2.1 Sample Selection

The necessary first step to start our analysis consists in selecting a relevant sample.

Given our setting and research question, we have considered as a relevant sample all the boats that landed in the UK before and/or after the legislation change.

The logic behind this definition is to identify the boats that have both the means and the interest to land and trade in the UK (or in the EU for UK boats). Then, simply through revealed preference, we identify these boats as the ones truly affected by the non-tariff barriers. This also allows us to filter out a considerable amount of non-relevant boats: those not genuinely interested in landing and trading in the UK (or in the EU for UK boats), which while technically affected by the barriers these might have no effect on them as were not going neither before nor after.

Therefore, with this in mind, we rely on the UK official statistics from MMO to first identify the nationalities of boats landing in the UK.[5] After, we launch a set of queries to the GFW API to obtain all the fishing boats IDs associated with these nationalities.[6] Once all the IDs 'were retrieved, we launched a new set of queries to obtain all the port visit events associated with these boat IDs. This allowed us to filter out the EU boats that never landed in the UK, keeping this way only the relevant observations for our sample.

[5]These nationalities were FRA, ESP, BEL, NOR, DEU, SWE, IRL, DNK, NLD and UK.

[6]This way, we reduce considerably the running times, and the size of the raw database extracted.

Then, with this filtered and refined list of IDs, we built our final dataset. Which compiles for the period 2018 to 2022 all the weekly history of relevant events (fishing events and port visits) carried out by these fishing boats.

Finally, we perform a trimming of the final dataset to eliminate potential mistakes and to filter out non-relevant port visits (e.g. technical stops or refueling). This consisted of retaining only those port visits recorded after a fishing event and those fishing events conducted prior to a port visit. This approach ensures a chronological record of each vessel's activity and behavior throughout its journey.

4.2.2 Sample Descriptives

Our final database contains 2,979 unique boats from 10 different nationalities. The number of boats of each nationality and the percentage that each nationality represents from the total is shown below in Table 1.

Table 1: Unique Vessels by Nationality

	Flag number	Flag share
BEL	78	2.62%
DEU	17	0.57%
DNK	66	2.22%
ESP	43	1.44%
FRA	142	4.77%
UK	2,255	75.7%
IRL	163	5.47%
NLD	35	1.17%
NOR	174	5.84%
SWE	6	0.20%
Total	2,979	100.00%

The country that represents the highest percentage in our sample is the UK, followed by Norway, Ireland and France with a much lower share. This strongly unbalanced sample is explained by how the relevant boats for the analysis are selected, keeping only the vessels that visited the UK before and/or after Brexit. Logically, the ships from the closest countries are the ones most likely to land in the UK.

Table 2 shows the distribution of port visits contained in our sample by nationality of the vessel (Flag share) and by country of destiny (Port country share).

Again, as we would have expected, most of the port visits in our sample are carried out

Table 2: Shares of Landings

	Nationality share	Port country share
BEL	3.98%	1.95%
DEU	0.41%	-
DNK	2.07%	3.24%
ESP	1.83%	1.24%
FRA	7.86%	7.71%
UK	68.07%	68.17%
IRL	4.55%	5.66%
NLD	1.98%	3.08%
NOR	9.06%	8.96%
SWE	0.20%	-

by UK boats, which are followed by Norway, France and Ireland. Similarly, these are the countries that receive the highest number of landings.

It is important to note that any of the boats under consideration do not land in Sweden during our period of interest. However, we actually have some landings in Germany that had to be dropped from the sample due to a lack of fish price data. However, the share of port visits to Germany was negligible, less than 0.5%.

5 Empirical Strategy

5.1 Utility Model

To measure the effect of non-tariff barriers on the UK fishing industry, we model each fishing boat landing decision based on a random utility discrete-choice model.

For this, we assume that boats are rational agents that maximise their own profit function, which is modelled through their utility function: boats choose to land in the country where they get the highest utility for their capture ($\approx$ higher profits). Consequently, landings can be regarded as the boat-level supply of fish to a given country.[7]

It is precisely this utility function what we use to assess our research question. For this, we model the introduction of the non-tariff barriers as a constant fixed-cost per landing for each affected boat (i.e. a EU boat landing in the UK or a UK boat landing in the EU). We do so by incorporating two different dummy variables that allow for asymmetric effects for UK and EU boats.

It is important to note that given our research question, we are modelling repeated landing choices of the same boats over time. Therefore, to account for the potential correlation of unobserved factors over time and to exploit the richness of our micro-level database to model individual heterogeneity, we employ a mixed logit model (Brownstone and Train (1999), Train (1998) and Train (2009)).

Then, for our baseline specification, the utility U_{ijt} that a fishing boat i gets from landing in country j at time t is modelled as:

$$U_{ijt} = \mathbf{w_{ijt}}\boldsymbol{\alpha} + \mathbf{z_{it}}\boldsymbol{\delta_j} + \mathbf{x_{ijt}}\boldsymbol{\beta_i} + \epsilon_{ijt} \qquad j = 1, 2, ..., J$$

Here, $\boldsymbol{\alpha}$ are fixed coefficients on $\mathbf{w_{ijt}}$, a vector of alternative-specific variables that include the distance[8] from the last fishing position of boat i to country j as well as a proxy variable

[7]Note we are only modelling the decision on where to land (extensive margin of the fish supply), and not how much fish they are landing (the intensive margin), since there is no data available on the latter at the individual boat level.

[8]In addition to working with the location of each port visit, we identify the port with the highest number of visits per country and establish it as the reference point for distance computation. The geographical operations were performed using GeoPandas library in Python for spatial operations on geometric types.

to measure the fish stock available at a given time t in the EEZ of country j.[9] This vector also includes one of our variables of interest: the non-tariffs barrier dummy for UK boats landing in the EU.

Then $\boldsymbol{\delta_j}$ are fixed alternative-specific coefficients on $\mathbf{z_{it}}$, a vector of boat-specific controls. This vector contains a dummy variable indicating if the boat is European or British as, not surprisingly, we observe in the data that boats tend to prefer going to their respective countries (the EU in case of European boats). In addition, it includes a variable that aims to capture the specialisation of the boats within our sample, as indicates the different type of fishing gear that the boat has. This variable is obtained from the GFW dataset.

The third part of our model, $\boldsymbol{\beta_i}$, captures the random coefficients on the vector of alternative-specific variables $\mathbf{x_{ijt}}$. These random coefficients vary over individuals in the population and allow to incorporate into the model correlation of choices across alternatives, which relaxes the IIA assumption required by the conventional multinomial logit model.[10] We model as random coefficients two important variables in our model: the non-tariffs barrier dummy for EU boats landing in the UK and the price.

The barrier dummy is modelled this way to allow for heterogeneity of the effect of barriers on EU boats, since we see in our data that even after the introduction of the non-tariff barriers a significant share of EU boats keeps landing in the UK.

Regarding the price variable, we allow for individual heterogeneity through the random coefficients due to how the variable is constructed. Using the MMO and EUMOFA data, we compute the price variable as a monthly weighted average price of all the fish sold in each country j and time t at the port fish auctions, where the weights are the quantities of the fish in question. The reason for this is technical, we lack data to identify the type of fish caught by individual boats and therefore we are unable to assign a relevant price for each boat, and as a consequence we have to resort to averages. Precisely because of this ”averaging effect”, we lose a lot of information which translates to a less informative

[9]We use fishing effort as a proxy for fish stocks following the methodology used by the Irish Marine Institute. This is based on the assumption that changes in fishing effort reflect changes in the stocks of fish. We extract this data from the GFW web page, which contains the Apparent Fishing Hours by zone. We aggregate them by total hours by country and month.

[10]Note that the mixed logit model estimates only the parameters of the distribution of $\boldsymbol{\beta_i}$, $f(\boldsymbol{\beta})$, not the $\boldsymbol{\beta_i}$ for each boat i per-se. In our case, since we assume that the random coefficients follow a normal distribution, $\boldsymbol{\beta_i} \sim N(\mu, \boldsymbol{\Sigma})$, then the mixed logit model actually estimates μ and $\boldsymbol{\Sigma}$.

regressor for some boats. In fact, this weighted average price might not even capture the actual price (and much less the price movements) that some boats would face if they were specialised in a type of fish that receives little weight in the weighted average price variable. Therefore, to take this into account, and more broadly, to allow for different preferences regarding price effects on utility, we fit a random coefficient as well to this variable.

Finally, the last term in our model is ϵ_{ijt}, a random term that follows a type I extreme value distribution.

5.2 Endogeneity Concerns

Since we are modelling a supply equation, it is important to note that there might be some correlation between the prices and the individual error terms due to the joint determination of demand and supply (Wright (1915)).[11] This would violate the required independence assumption for consistency (Berry (1994)).

To tackle these endogeneity concerns in discrete choice models, Petrin and Train (2010) propose a control function method. The idea behind this approach consists on conditioning on the part of the endogenous variable that is correlated with the error term, so that the remaining variation left of the endogenous variable is independent of the error term and can be estimated consistently.

To implement this, the authors propose a two-step approach. First, the endogenous variable is regressed on (i) all the exogenous variables entering utility for any of the choices and (ii) variables that do not enter the utility function directly but that affect the endogenous variable (the instruments). The residuals of this regression are retained and used to calculate the control function. Second, the discrete choice model is estimated with the control function as an additional variable or variables.

In our setting, we use a demand shifter as an instrument for the endogenous price variable. In particular, we employ the number of nights spent in a country by foreign tourists every month obtained from EUROSTAT. This variable influences prices through the demand

[11] Although this potential endogeneity concern is likely to be reduced because we employ weighted average prices rather than boat-level individual prices, which lessens the link between the supply decision and the effect of price.

channel since it affects the number of potential consumers - in fact, it shows a strong correlation with our price variable that is confirmed with the results of the first stage regression. On the other hand, this instrument is not related to the supply equation.

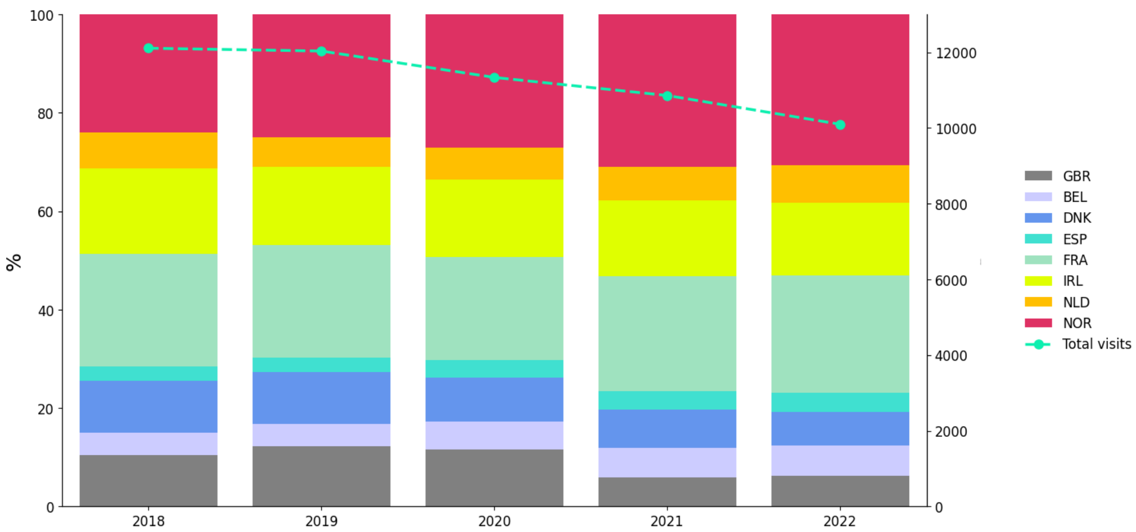
Finally, to fit our final discrete choice model, we opt for the simplest version of the control function, where it enters linearly into the utility function of the discrete choice model.

6 Results

6.1 Preliminary Results

After an exploratory analysis of our sample, we already observe a reduction in landings in the UK by ships belonging to member countries of the EU, coinciding with the departure of the UK from the European internal market. Figure 2 captures the number of landings by EU boats in the different countries of destination, computed as a share of the total number of landings realised by EU boats. We do not see a significant change of these shares in 2020 as an effect of the COVID-19 pandemic. We do observe, however, changes in landing decisions in 2021, that are maintained in 2022. The percentage of landings in the UK dropped approximately from 10% to 5%. This share seems to be transferred to Norway and France, the closest countries. It is worth noting, that the total number of landings presents a downward trend since 2019.

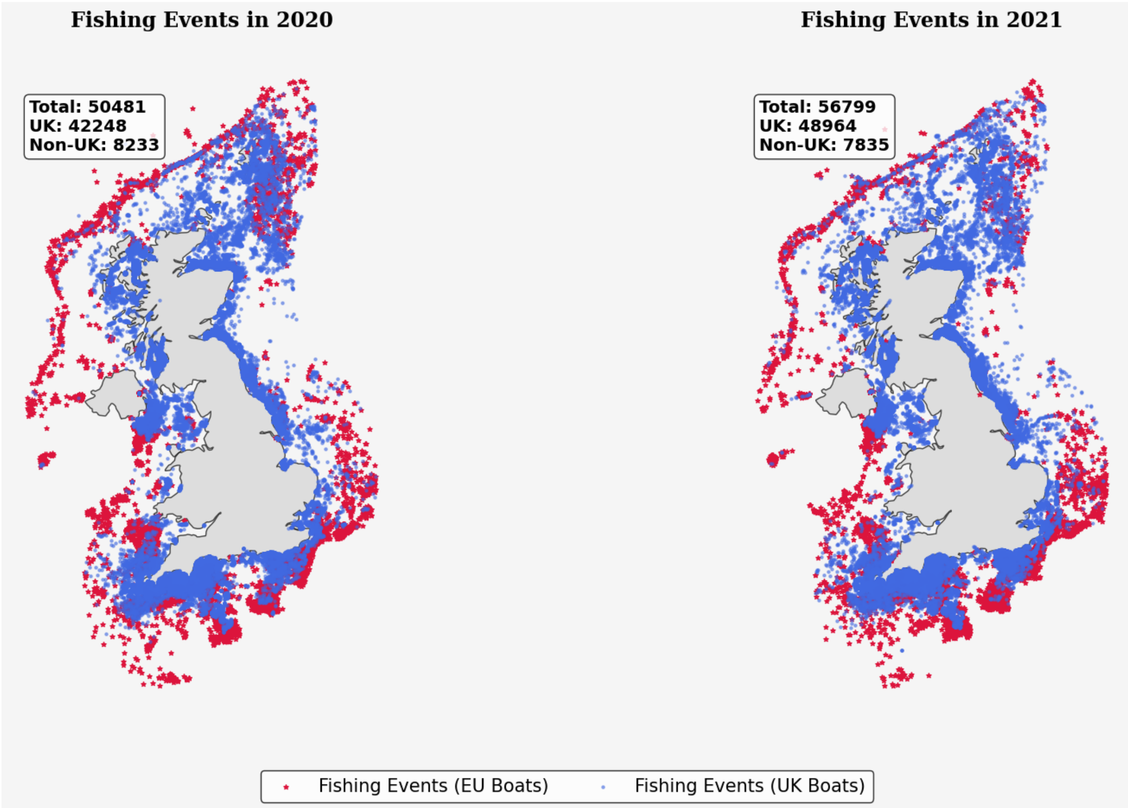
Figure 2: Share of Landings by Country of Destination (EU Boats)



In the case of boats from the United Kingdom, we do not observe a significant change through the time period of interest. These boats land almost exclusively in the UK and this is not significantly affected by COVID or by Brexit. The total number of landings does reduce in 2020 but returns to previous values in 2021.

Despite the changes in the amount of landings in the United Kingdom and the change in the decision in country of landing for some vessels, there is not a significant change in the

Figure 3: Fishing Events by Year and Flag



fishing pattern and amount of fishing events, as shown in Figure 3.

6.2 Econometric Model Results

The model confirms the intuition provided by the preliminary analysis. We run three different versions with different combinations of regressors. The estimates of the mixed logit model are showed in Table 3. From these coefficients we can only interpret the sign. A negative sign would mean, that if the value of that regressor increases for one alternative, the probability of choosing that alternative decreases. We allow for random coefficients in the Barriers suffered by EU ships in all models, and in Price for Model 3. The argument behind it, is that there exists a high heterogeneity of how these variables affect the utility of the different vessels. Some ships might have a different commercial strategy with the fish they land, which could make them less sensible to non-tariff barriers, or could have special agreements with ports in the UK. In the case of prices, each vessel receives a different price depending on the species they land. In our model, prices are modelled as a monthly weighted average by country, and hence is common for all boats landing in the same country and month. Allowing for random coefficients partially corrects this limitation.

The coefficients of our variables of interest, (Barrier UK and Barrier EU) remain stable through all models. The effect of ”Barrier UK”, the non-tariff barriers UK vessels face when landing in the EU, presents a positive sign. Nonetheless, EU boats are negatively affected by the trade barriers imposed in the United Kingdom. This result is in line with what we observed in the preliminary analysis. We observe a high variance in the effect of Barriers for EU boats, with the effect being even positive for some boats.

Table 3: Results Models

	Model 1	Model 2	Model 3
Barrier UK	0.13***	0.13***	0.11***
Barrier EU	-3.45***	-3.50***	-3.75***
SD (Barrier EU)	3.53	3.59	4.48
Price	0.024*	0.025’	-0.98***
SD (Price)			1.30
Distance	-0.68***	-0.68***	-0.70***
Fishing Effort	0.025***		0.033***
Gear Type	NO	YES	YES
Europe Dummy	YES	YES	YES
BIC	116,621.6	112,135.9	92,767.24
AIC	116,409.9	111,863.7	92,474.85
Observations	1,413,928	1,413,928	1,413,928

Note: *** significant at the 0.1% level, ** significant at the 1% level, * significant at the 5% level, and ’ significant at the 10% level.

The coefficients of prices are not intuitive. For the first two models it presents a positive sign, only significant to a 5% level for Model 1 and to a 10% level for Model 2. In Model 3 the sign changes to negative. The standard deviation of this effect, shows that for some vessels there is a positive sign. The explanation behind this surprising result might be the way the regressor is constructed. Price does not represent exactly the monetary value each vessel receives, but rather the value of the fish landed in each country. Hence, the price of a country does not accurately represent the price an individual vessel receives.

The regressors of distance and stock of fish (Fishing Effort) do provide intuitive results. A vessel is more likely to land in a country the closer it is to its fishing spot, and if this country has a higher stock of fish.

To compare the different specifications of our model we use the Akaike's information criteria.[12] We also used for further robustness the Bayesian information criterion.[13] Model 3 presents the lowest value, which means that is the model that fits the data the best. We use only this model in further analysis.

Using the results of this model, we compute the probability of landing in every country through the years, and as a counterfactual, we compute the same probabilities if there were no barriers. In Figure 4 we present these probabilities for landing in the UK for EU boats, and in Figure 5 we present them for Ireland, France and Norway. The remaining countries were not added, because they do not show any significant change.

It can be observed, that these probabilities drop from a 17% to a 10%. However, this probability would have remained stable if Brexit would not have happened. It should be noted, that these probabilities are slightly overestimated, as they are higher than the actual values we observe in the preliminary analysis. In Models 1 and 2, where we do not allow for random coefficients in prices and the sign of the estimate for price is positive, we obtained more accurate results. However, the implications and interpretations of the result are the same for all models.

For the other countries we observe a diversity of effects. Norway and France have an increased probability of landing in 2021 and 2022, but for the case of Norway this increase would have been almost identical without barriers. Ireland, on the other hand, would have

[12]AIC is defined as: $AIC = 2lnL + 2k$ where $ln(L)$ is the maximized log-likelihood of the model; k is the model degrees of freedom calculated as the rank of variance–covariance matrix of the parameters. Akaike (1974)

[13]BIC is defined as: $BIC = 2lnL + klnN$ where $ln(L)$ is the maximized log-likelihood of the model; k is the model degrees of freedom calculated as the rank of variance–covariance matrix of the parameters. Also, N is the number of observations used in estimation or, more precisely, the number of independent terms in the likelihood. Kass and Raftery (1995) Raftery (1995)

experienced a bigger decrease if Brexit would not have been realised. It is clear that this countries, due to its proximity to the UK, receive now a higher share of EU boats. We can also interpret, that there is a change in the dynamics of the fishing industry that are not directly related to Brexit.

Figure 4: Probability of Landing in the UK (EU Boats)

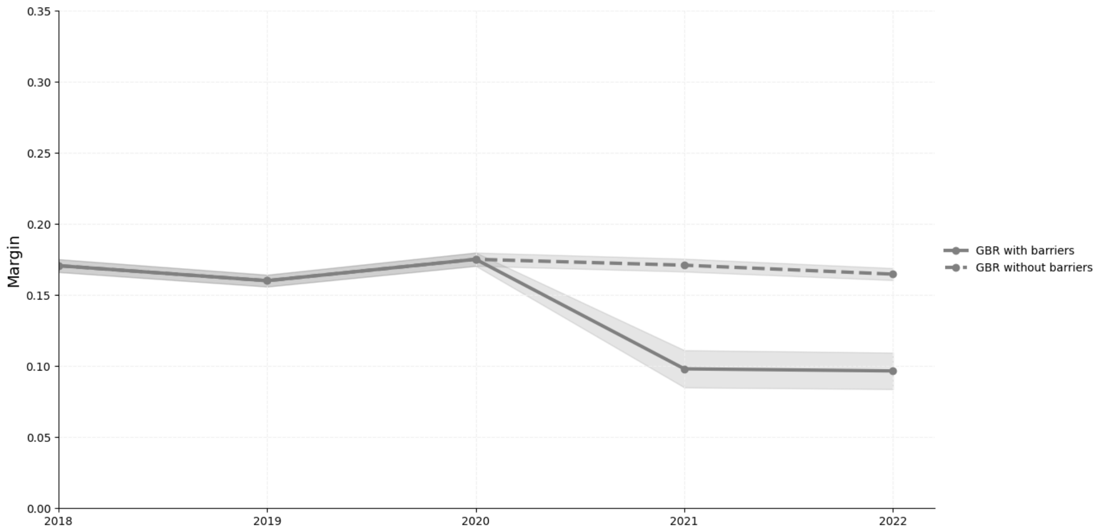
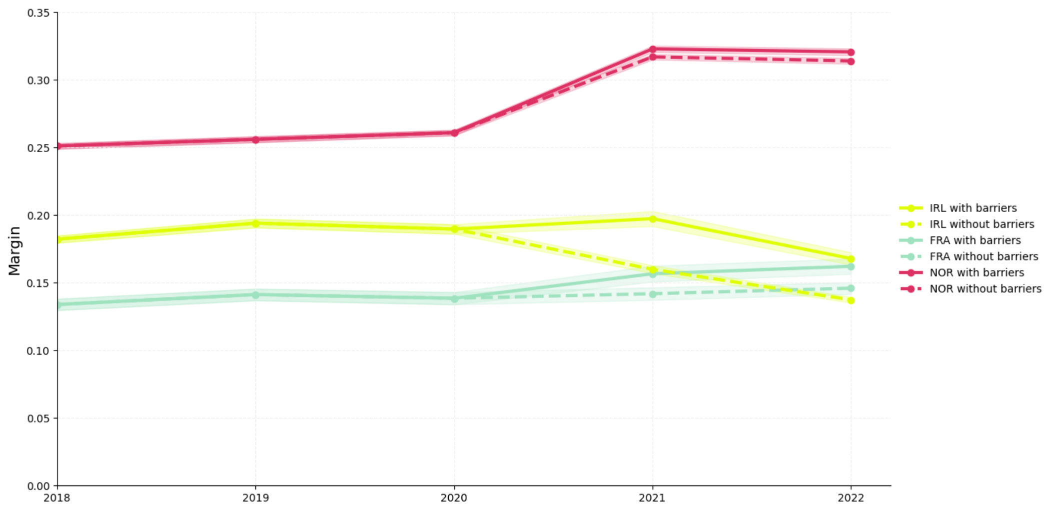


Figure 5: Probability of Landing (EU Boats)



6.3 Producer Surplus

To better understand the implications for vessels belonging to the European Union and the United Kingdom of the non-tariff barriers, we compute the difference in utility between the years after Brexit and the utility in the same years in a scenario without non-tariff barriers. We predict the probabilities of each landing in 2021 and 2022 if there were no barriers, and we select the destination with the highest probability and extract the utility each vessel would have received if they would have gone to that destiny. By doing this, we can compare the utility obtained, with the potential utility these vessels could have achieved if Brexit would not have happened.

We estimate a loss in utility of 13.84% for EU boats and of 2.49% for UK boats. Given that our sample of EU boats contains only the vessels that went to the UK during the period of interest, it ts logical that the estimated loss represents a higher percentage. We can conclude, however, that the introduction of non-tariff barriers affected negatively the fishing companies of both origins.

7 Conclusion, Discussion and Policy Reccomendations

In this section we present possible issues with our analysis, propose further advances in the study of the issue, and then suggest some policy recommendations.

In our model we assume that boats are rational agents maximising their profit function - this may not fully encapsulate the complexity of decision-making processes in the fishing industry. We are not able to account for the fact that some vessels could be linked by a common owner. This, even though it's not of particular concern given the relative low concentration of the industry, may provide further insights that we couldn't account for. Furthermore, factors such as tradition, local regulations, and social ties could also play significant roles but are not explicitly accounted for in our model leaving space for future research.

Further research could look into the environmental implications of the imposition of these non-tariff barriers, and the overall change in sustainability of the industry.

In the utility framework, our results find a greater drop in utility for EU vessels compared to the UK ones. This is likely due to the fact that we are not considering all EU boats, but only the ones that prior to the introduction of the policy were conducting operations in the UK. On the other hand, we consider in our sample the whole population of boats with UK flag.

In order to mitigate the adverse effects of non-tariff barriers, several policy recommendations can be proposed. Simplifying and harmonising customs checks and documentation requirements can reduce delays and administrative burdens for fishing vessels. Providing financial support or subsidies to fishermen affected by increased costs due to non-tariff barriers can help maintain profitability. Additionally, investing in port infrastructure can improve efficiency and reduce turnaround times for vessels, ensuring the freshness and quality of landed fish.

By adopting these policy measures, stakeholders can better navigate the post-Brexit regulatory environment, solidifying the sustainability and competitiveness of the fishing industry.

To conclude, this study has analysed the impact of non-tariff barriers introduced by Brexit on the landing decisions of fishing vessels. Using a discrete choice model, we examined how these regulatory changes influenced the decision-making processes of UK and EU fishing vessels. Our findings reveal significant shifts in landing preferences post-Brexit, with economic and operational challenges for the fishing industry. In terms of producer surplus, we find a loss in utility for EU boats of almost 14% and for UK boats of 2.5%.

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