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"Flags of Deceit:" Re-Flagging Trends among Sanctioned Ships in the Russian Shadow Fleet

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Abstract. Since the beginning of its invasion of Ukraine, Western nations have imposed sanctions on Russian trade, in particular its fleet of oil tankers. To evade these sanctions, Russia has introduced a fleet of ships that bypass, through different means, the sanctions imposed against the country. Using open, collated data on sanctions against this "shadow fleet," this paper provides the first quantitative evaluation of re-flagging among sanctioned Russian vessels. While initially often sailing under classical "flags of convenience" (FOC), the maritime journal Lloyd's List has recently noted that increasingly ships in this fleet are re-flagged to countries with even less rigorous controls than classical FOC countries. These "flags of deceit" (FOD) are claimed to welcome older ships, often under fake identifiers. In this paper, we confirm that Russia is, indeed, re-flagging to countries like Cameroon and Sierra Leone, while also providing more detail on patterns in the tonnage and age among different FODs.

Submission type. analysis, dataset, case study

BoK Concepts. [AM11] Network Analysis, [TA12] EO for societal and environmental challenges.

Keywords. network analysis, flags of convenience, flags of deceit, Russia, sanctions

1 Introduction

1.1 The Rise of the Dark Fleet

Following the Russian invasion of Ukraine in February 2022, Western nations imposed sanctions against Russian oil exports and shipping, including a price cap on Russian oil by G7 nations and an import ban by the European Union (EU) (e.g. Spiro et al., 2025; Johnson et al., 2023). In response to these measures, tankers and ships moving to and from Russia started pursuing different strategies of evasion, from ship-to-ship transfers at sea to the transfer of flags to open registries in nations with little to no oversight mechanisms, bypassing Western ownership and insurance structures of maritime governance (e.g. Fernández-Villaverde et al., 2025; Ballinger, 2024). Today, this "shadow fleet" (Parlov and Sverdrup, 2024) is estimated to include up to 1942 ships (Windward, 2025), of which 882 are sanctioned by Western governments. Based on this estimate, these ships would transport up to 17% of all seaborne crude oil and make up 18–19% of the global tanker fleet (Adams and Devlin, 2026).

This fleet is not only in violation of the sanctions that seek to end Russian aggressions in Ukraine, but also an imminent security and environmental risk on the global oceans (Rodriguez-Diaz et al., 2025). Shadow fleet ships are generally much older than other tankers (e.g. Hilgenstock et al., 2024), with recent spills in the Kerch Strait (Cheetham et al., 2025). Moreover, ships in the shadow fleet have been connected to damages to international telecommunications cables in the Baltic (e.g. Ringbom, 2025; Pulk et al., 2026). Due to the offshore flagging of these ships, their ownership is often opaque even in the notoriously opaque domain of maritime logistics (e.g. van Fossen, 2016), creating a range of challenges for holding ship owners accountable.

1.2 From Flags-of-Convenience to Flags-of-Deceit

Questionable activity on the world oceans is often connected to the system of "flags of convenience" (FOCs) (e.g. Campling and Colas, 2021): Ships register in so called "open registries" in countries other than their own, in order to avoid taxes and labour regulations (e.g. Campling and Colás, 2023). Originally developed in the 1920s, when American vessels started registering in Panama, several other countries developed registries later in the 20th century, including Liberia, the Marshall Islands, Malta, and Cyprus (e.g. Carlisle, 1981; Barton, 1999; Campling and Colás, 2023; van Fossen, 2016).

As we shall see, ships that are sanctioned today as operators in the Russian shadow fleet have a history of using these classic FOC countries (e.g. Filho, 2025). However, pressure from sanctioning countries has pushed some FOC countries to crack down on shadow fleet flagging (e.g. Raanan, 2025). In a recent article, the private maritime analytics company Lloyd's List noted that shadow fleet vessels have been re-flagging to a new kind of open registry with even less oversight than the ones in classic FOC countries (Lloyd's List, 2024). While stopping short of naming any countries providing these "flags of deceit," (FODs) other analyses suggest that they include countries like Cameroon, Sierra Leone, Oman, Mozambique, Iran, and Gabon (e.g. Filho, 2025; Windward, 2025; Adams and Devlin, 2026). Often, these ships are not only older, but also using fraudulent identifying numbers (e.g. Lloyd's List, 2024).

As compelling as this story is, no quantitative empirical study has been published on the emergence of these FOD actors. Building on both qualitative (e.g. Rodriguez-Diaz et al., 2025; Filho, 2025) and quantitative (e.g. Fernández-Villaverde et al., 2025) work looking into the composition of the shadow fleet, this article provides the first quantitative analysis on re-flagging patterns among sanctioned Russian vessels. The article starts with a presentation of the data and methods, followed by a network analysis complemented by statistical models on variance in tonnage and age by flag among sanctioned vessels.

2 Data & Methods

2.1 Data Collection

The data for this paper were collected from OpenSanctions, a website that gathers and harmonizes sanctions data from around the world.[1] Specifically, we used the dataset on "Maritime-related sanctions."[2] Previously, OpenSanctions data has, among other things, been used to map networks of Russian oligarchs (Montenarh and Marsden, 2024), the use of cryptocurrencies during geopolitical conflicts (Alexakis et al., 2024), and offshore leak networks (Joaristi et al., 2019).

We started from a .csv file that contains the IMO numbers of all the ships in the Maritime-sanctions dataset[3] and used the `/match/maritime` API endpoint to gather information on all the ships in the file on February 9th 2026 within the topic `mare.shadow` for detailed information, including current and former flags. This returned 807 ships in total, a number similar to what is included in other datasets on the *sanctioned* ships of the Russian shadow fleet.[4]

Ships are generally identified by two numbers: An International Maritime Organisation (IMO) number and an Maritime Mobile Service Identity (MMSI) number (Bereta et al., 2021). Whereas the IMO number is a unique permanent identifier assigned to any propelled, seagoing vessel of 100 gross tons and more when the vessel was constructed, a new MMSI number is assigned to a vessel whenever it changes flag. Indeed, the first three out of the nine digits of the MMSI allow us to identify the flagging country of the vessel.

In the detailed OpenSanctions data, the flags of every ship are organized as two unordered sets: one for past flags, and another for current flags. While a ship technically only sails under a single flag, the inclusion of several current flags can result from a variety of reasons. As noted above, the flag of a vessel is usually deduced from its MMSI number. A vessel can modify the MMSI code or broadcast several MMSI codes from different devices (Guan et al., 2023). It is also possible that the inclusion of more than one current flag is a result from ambiguity in the sanctions data. Be that as it may, the median number of present flags is 1, while the mean is 1.6. In other words, most ships still had only one current flag. For past flags, the median is 3 while the mean is 3.62. Ten ships were missing flag data entirely, reducing the effective sample from 807 to 797.

2.2 Re-flagging Networks

We now present the methods for producing a network of re-flagging practices between different flagging nations using flag changes registered to individual ships. The calculations in this section are presented verbally, but precise mathematical equations can be found in Appendix A.

First, to explore the transition between flags, we build a network using the unordered sets of current and past flags, with flagging countries as nodes and ships as edges (as seen in Equation A1). The edges are normalized using the node counts of both the previous and current flags. For instance, if a ship had three previous flags and one current flag, the in- and out-degree contribution of these flags would be 0.333. If the ship had two current flags, this number would instead be 0.166. In order to get the final edges between flagging nations, we sum up the normalized weights from all ships that are or were flagged under a given nation.

Then, to get a rough sense of flag transition dynamics, we calculate three scores for each country, with self-loops excluded. The sink and source scores capture how asymmetric a country's flag flows are, while the recycler score identifies countries with high throughput in both

[1] https://www.opensanctions.org/

[2] https://www.opensanctions.org/datasets/maritime/

[3] The .csv file is updated on an almost daily-basis: https://data.opensanctions.org/datasets/20260209/maritime/maritime.csv

[4] At the time of writing in February 2026, the anonymously operated website FleetLeaks included 882 ships. https://fleetleaks.com/vessels/

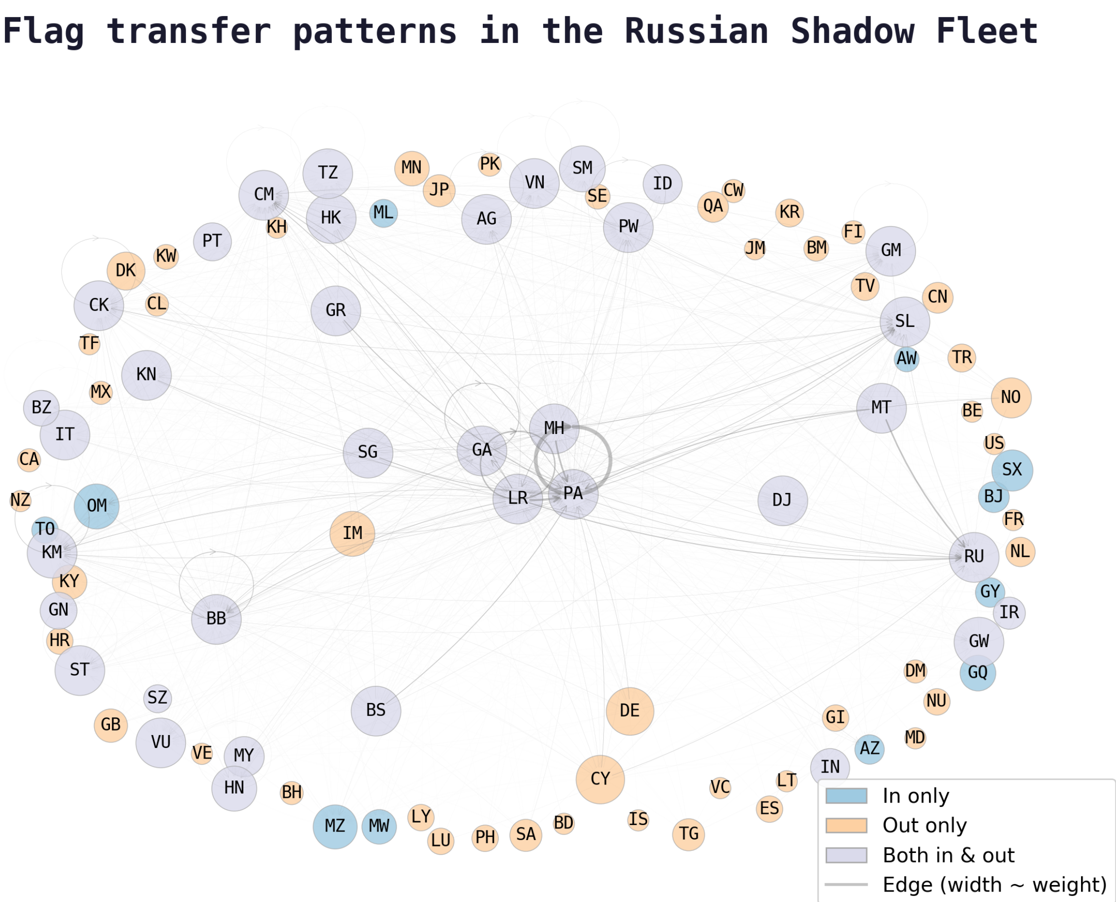

Figure 1. The figure shows a directed network where receiving nodes are current flags and sending nodes are past flags. The edges are formed by ships that the flags had in common over time, with weights adjusted in cases where a ships has more than one past or present flag. The in- and out-degree per flag can be seen in the map in Figure 2.

directions. The sink score (Equation A2) is calculated by dividing the in-degree by the out-degree, with the inverse calculation for the source score (Equation A3). For the recycler score (Equation A4), we divide the sum of the in- and out-degree by their absolute difference. In each case, we add 1 to the denominator (additive smoothing) to avoid division by zero.

Third, we also calculate a "self-loop weight" (Equation A7) to identify countries that have flagged the same ship more than once. For each vessel, we add a normalized contribution whenever the same flag appears in both its past and current flag sets, then sum these contributions across all vessels.

Fourth, we explore the net flow of ships and tonnage to and from each flag. The net ship flow (Equation A8) is simply in-degree minus out-degree. The net tonnage flow (Equation A9) is calculated the same way, but with each vessel's contribution weighted by its tonnage. Finally, we also calculate a normalized tonnage balance score (Equation A12), which ranges from -1 (pure source) to 1 (pure sink).

2.3 Statistical Models

To test the claim that flags of a certain kind tend to harbor older ships, we fit a Poisson regression model with age as outcome and flag as categorical predictor. We additionally test for the effect of flag on the log-normally distributed vessel tonnage. Both models are fitted in `PyMC` (Abril-Pla et al., 2023). Model specifications and posterior distributions of flag-level effects can be found in Appendix B.

2.4 IMO Validity

Finally, we also test the validity of the IMO numbers using the checksum that allows for the detection of any fake IMO numbers (Park et al., 2023). For the precise calculation, see Appendix C. However, as OpenSanctions gets the IMO numbers from the sanctioning authorities, as well as a number of external databases, all numbers are valid. Consequently, we exclude this part from the results and discussion and reserve all notes on it for the appendix.

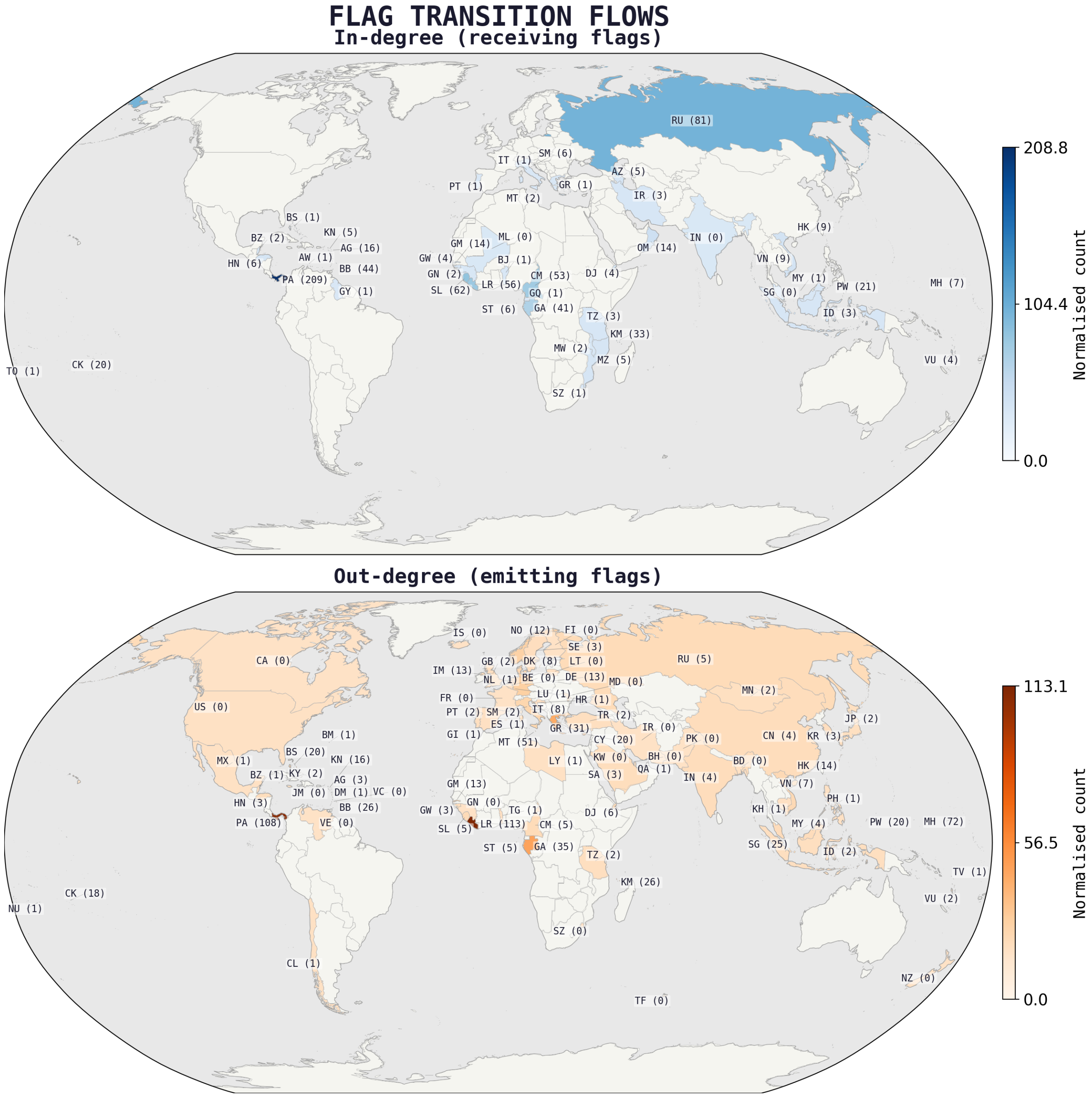

Figure 2. The upper figure shows the number of ships per country associated with a flag currently, the lower map shows the number of ships associated with a country previously. The numbers in parenthesis represent the rounded in- and out-degrees as seen in Figure 1.

Table 1. Flag registries singled out by Windward (Windward, 2025; Adams and Devlin, 2026). Status as classical FOC based on tables in Petrossian et al. (2020) and van Fossen (2016).

Registry	Classical FOC	Emergent FOD	Notes
Antigua and Barbuda (AG)	✓		Major sink.
Azerbaijan (AZ)		✓	Top sink, newer ships.
Barbados (BB)	✓		Top recycler and self-looper.
Belize (BZ)	✓		
Cameroon (CM)		✓	Major sink, currently de-flagging.
Comoros (KM)			
Cook Islands (CK)	✓		
Curaçao (CW)			
Djibouti (DJ)			
Gabon (GA)		✓	Top recycler and self-looper.
Guinea (GN)			
Guinea-Bissau (GW)			Smaller ships.
Guyana (GY)			
Honduras (HN)	✓		
Hong Kong (HK)	✓		Top recycler.
Iran (IR)			
Liberia (LR)	✓		Top self-looper, smaller ships.
Marshall Islands (MH)	✓		Major source, smaller ships.
Mongolia (MN)			
Mozambique (MZ)	✓		Major sink.
Oman (OM)		✓	Sink-only, newer ships.
Palau (PW)			
Panama (PA)	✓		Top recycler, self-looper, and major sink.
Russia (RU)			Major sink, smaller ships.
San Marino (SM)			Major sink, registry established 2021.
São Tomé and Príncipe (ST)			
Sierra Leone (SL)		✓	Major sink.
St. Kitts and Nevis (KN)			Older ships.
Tanzania (TZ)			
Togo (TG)			
Tuvalu (TV)			
Vanuatu (VU)	✓		
Vietnam (VN)			Top recycler.

2.5 Data and Software Availability

The Jupyter notebook for reproducing this paper can be found on GitHub at https://github.com/maybemkl/AGILE-2026 under a permissive MIT license, along with the relevant data from OpenSanctions and scrapers to replicate the data collection process.

3 Results

3.1 Re-flagging Networks

We begin the network analysis by looking at four tables that enumerate the top 10 flagging countries for sinks (Table 2), sources (Table 3), recyclers (Table 4), and self-loopers (Table 5). The results are summarized in Table 1, which contains a list of emerging open registries connected to the shadow fleet as reported by private maritime analytics company Windward AI (Windward, 2025), along with complementing information from Lloyd's List.

Table 2. Top sink flags: countries receiving more flag transitions than they emit

Flag	In-deg.	Out-deg.	Sink score
Russia (RU)	80.08	4.29	15.12
Oman (OM)	14.08	0.00	14.08
Cameroon (CM)	51.84	3.28	12.11
Sierra Leone (SL)	61.64	4.64	10.93
Antigua & Barbuda (AG)	13.61	0.52	8.97
Azerbaijan (AZ)	5.00	0.00	5.00
Mozambique (MZ)	4.83	0.00	4.83
Panama (PA)	157.26	56.65	2.73
San Marino (SM)	5.24	1.00	2.62
Iran (IR)	3.00	0.25	2.40

Sink score = in-degree / (out-degree + 1). Self-loops excluded.

Table 3. Top source flags: countries emitting more flag transitions than they receive

Flag	In-deg.	Out-deg.	Source score
Malta (MT)	1.38	50.42	21.23
Greece (GR)	0.50	31.15	20.77
Singapore (SG)	0.25	25.00	20.00
Cyprus (CY)	0.00	19.62	19.62
Germany (DE)	0.00	13.07	13.07
Marshall Islands (MH)	4.39	69.83	12.96
Isle of Man (IM)	0.00	12.60	12.60
Norway (NO)	0.00	12.24	12.24
Bahamas (BS)	0.83	19.35	10.56
Denmark (DK)	0.00	7.99	7.99

Source score = out-degree / (in-degree + 1). Self-loops excluded.

Table 4. Top recycler flags: countries both receiving and emitting flag transitions

Flag	In-deg.	Out-deg.	Recycler score
Gambia (GM)	12.12	11.88	19.37
Palau (PW)	16.91	15.66	14.45
Cook Islands (CK)	15.73	13.92	10.56
Gabon (GA)	31.03	25.06	8.06
Comoros (KM)	26.40	19.41	5.74
Vietnam (VN)	7.64	5.46	4.12
Hong Kong (HK)	7.89	12.94	3.45
Barbados (BB)	36.16	17.72	2.77
Liberia (LR)	38.18	94.83	2.31
Panama (PA)	157.26	56.65	2.11

Recycler score = total degree / (1 + |in − out|), minimum degree threshold = 5. Self-loops excluded.

In terms of sinks, as seen in Table 2, the countries that currently have many flagged ships under them, while they had no flagging history prior to that, are Russia (RU), Oman (OM), Cameroon (CM), Sierra Leone (SL), and Antigua and Barbuda (AG). Smaller inflows with almost no or no outflow at all include Mozambique (MZ), San Marino (SM)—which started providing flags only in 2021—and Iran (IR). The list further includes Panama (PA), but Panama has also lost a lot of ships in the network. Among the sink flags, most countries are not what we would call classical FOC countries, as defined in previous research (e.g. Petrossian et al., 2020; van Fossen, 2016). Only Panama (PA) and Antigua and Barbuda (AG) are really classical FOCs, with Mozambique (MZ) as an edge case (Meade and Diakun, 2025).

By contrast, when turning to the sources in Table 3, we find countries that are very classical FOCs, including Malta (MT), Cyprus (CY), the Marshall Islands (MH), the Isle of Man (IM), Norway (NO), and the Bahamas (BS). Although Denmark (DK), Germany (DE), and Greece (GR)—a classic shipping nation (Khalili, 2021)—are among the sources, this is likely due to actual and real changes in ownership, more so than flagging

Table 5. Flags re-assumed after previously being dropped (self-loops)

Flag	Self-loop w.	In-deg.	Out-deg.
Panama (PA)	51.53	157.26	56.65
Liberia (LR)	18.23	38.18	94.83
Gabon (GA)	10.39	31.03	25.06
Barbados (BB)	8.34	36.16	17.72
Comoros (KM)	6.68	26.40	19.41
Cook Islands (CK)	4.27	15.73	13.92
Palau (PW)	3.95	16.91	15.66
Antigua & Barbuda (AG)	2.89	13.61	0.52
Marshall Islands (MH)	2.20	4.39	69.83
Gambia (GM)	1.58	12.12	11.88

A self-loop indicates at least one vessel that returned to a previously held flag.

for convenience. The only newer FOC country here is Singapore (SG).

Among the recycling countries in Table 4, we find classic FOCs—including the Cook Islands (CK), Barbados (BB), Liberia (LR), and Panama (PA)—and emerging actors—including Gambia (GM), Palau (PW), Gabon (GA), Comoros (KM), Vietnam (VN), Hong Kong (HK). The same goes for self-loopers in Table 5, where we find essentially the same countries with only a small difference to recyclers.

The sink and source patterns are, after removing self-loops, accounted for in Figure 3. Looking at this table, we can see that the flags that have the greatest net in-flow of ships are, in addition to Russia (RU) itself and the classic FOCs Panama (PA) and Barbados (BB), emerging FOD actors like Sierra Leone, Cameroon, Oman, Gabon, Azerbaijan, and Mozambique which has, depending on the source, been classified as a classic (Petrossian et al., 2020) or emergent FOC (Meade and Diakun, 2025). The out-flow is largely from classic FOC countries, like the Marshall Islands (MH), Liberia (LR), and Malta (MT).

Figure 4 offers a complementing view, with the balancing ratio defined in Equation A12 on the y-axis and net tonnage on the x-axis. Once again, we can observe that unconventional FOCs are emergent, as seen by the positions of Sierra Leone (SL), Cameroon (CM), and Russia (RU) itself in the upper right-corner of the plot. At the same time, the trend away from classic flags like Liberia (LR) and the Marshall Islands (MH) is unusually clear here.

3.2 Statistical Models

In contrast to the descriptive network analysis, the statistical models provided more inconclusive results. There was simply no very significant variance in ship age and tonnage between the flagging countries. Some exceptions stand out.

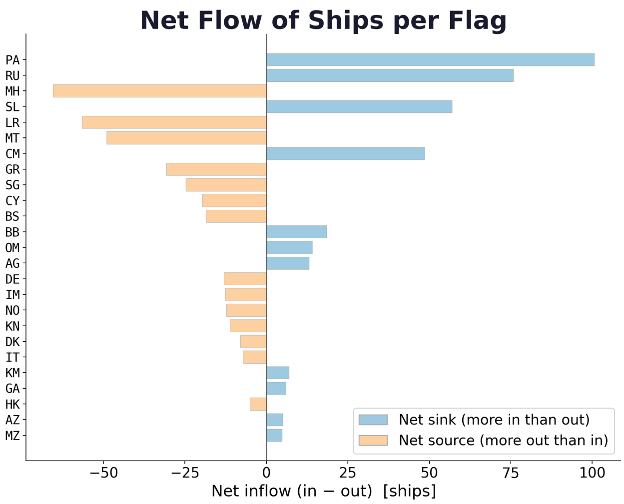

Figure 3. The top 25 sinks and sources.

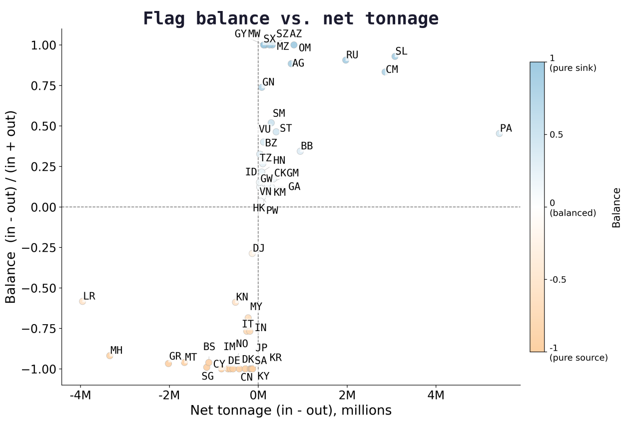

Figure 4. Flag balance (as defined Equation A12) plotted against net tonnage activity (in - out).

On the one hand, we were able to find preliminary evidence that older ships have been re-flagged to Iran (IR) and Saint Kitts and Nevis (KN), while newer ships had been re-flagged to Oman (OM) and Azerbaijan (AZ). At the 95% credible interval, Azerbaijani ships are about 60% of the average age of other ships, so roughly 12 years compared to the average of 21 years. Closer to the 50% credible interval, Omani ships are about 80% of the average age (17 years), whereas ships from Saint Kitts (KN) and Nevis as well as Sint Maarten (SX) are somewhat older.

On the other hand, we found that larger ships are statistically more likely to be flagged under San Marino (SM) and São Tomé and Príncipe (ST) as well as Hong Kong (HK), Guyana (GY), and Oman (OM). By contrast, smaller ships tended to sail under classical FOCs such as the Marshall Islands (MH) and Liberia (LR), as well as emergent FODs such as Palau (PW), St. Kitts and Nevis (KN), and Russia (RU) itself. At the 95% credible interval, Russian ships are about 50% of the average tonnage of other ships, so 28,500 against roughly 57,000. By contrast, ships flagged under San Marino (SM) as well as São

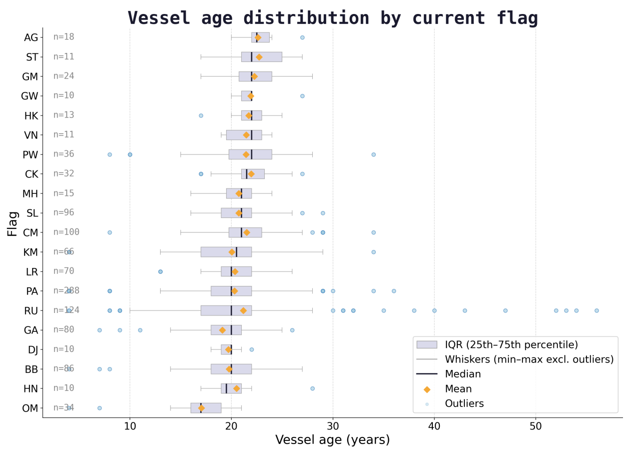

Figure 5. The age of sanctioned ships by flag.

Tomé and Príncipe (ST) tend to be much larger than other ships. Closer to the 50% credible interval, ships under the Hong Kong (HK) flag also tend to be larger, while ships from Liberia (LR), Saint Kitts and Nevis (KN), as well as Indonesia (IN) tend to be smaller.

4 Discussion

Our analysis has provided empirical evidence for a development that private maritime companies have long highlighted: The Russian shadow fleet has re-flagged from classic registries such as Liberia (LR), Cyprus (CY), Malta (MT), Singapore (SG), the Marshall Islands (MH), the Bahamas (BS), and the Isle of Man (IM) to countries such as Oman (OM), Cameroon (CM), Sierra Leone (SL), Azerbaijan (AZ), as well as Russia (RU) itself and Iran (IR). At the same time, some classic open registries—in particular Panama (PA)—remain important sources of vessel flagging in the dark fleet, along with countries that have been designated as flags of convenience earlier in the 2000s, including Mozambique (MZ).

Meanwhile, the network that we showed in Figure 1 is constantly evolving. Recently, Lloyd's List reported that Cameroon (CM) has responded to sanctions against Russian vessels through a massive de-flagging operation (Raanan and Meade, 2026). Some emergent trends like these are captured in the data——such as Oman (OM) rising to the fore of re-flagging operations in late 2025 (Windward, 2025)——while others——like the de-flagging of Cameroon (CM)——are already underway as we write this article.

The two maps in Figure 2 suggest that Africa is emerging as a major hub for re-flagging operations, while Central America and the Caribbean remain important for the practice. These findings are in line with what has been reported within the commercial maritime analytics world (e.g. Windward, 2025; Lloyd's List, 2024; Adams and Devlin, 2026). Nevertheless, these movements seem to have internal patterns that are still somewhat elusive.

For instance, as suggested by Figure 4, ships of varying capacity are de-flagged from and re-flagged to different countries.

While our statistical models struggled to find very consistent patterns in terms of the age and tonnage of ships by flag, the explanation might be simple: The data of this study consists entirely of sanctioned shadow fleet ships. A comparison between ships in the shadow fleet and outside of it would, in all likelihood, be much more generative. As can be seen in Figure 5, the average age of the sanctioned ships in our data is 20.6 years, with some Russian (RU) ships as old as 50 years. By contrast, according to numbers from the consultancy firm Clarksons PLC (Woyda and Case, 2025), the average age of the global tanker fleet was roughly 13 years in 2025. According to many analysts, shipping accidents are much more likely with ships that are more than 20 years old (e.g. Meade, 2025).

5 Conclusions

This paper has provided the first quantitative assessment of re-flagging practices within the sanctioned vessels of the Russian shadow fleet. While flagging practices are rigorously studied within maritime analytics and consultancy companies like Windward and Lloyd's List, publicly available, peer-reviewed, and quantitative research on re-flagging practices is scarce (for an excellent exception in the domain of fishing, see Park et al., 2023).

We have demonstrated that the recent designation of Lloyd's List of a new, emergent cluster of flaggers of "deceit" is clearly visible in data on flagging patterns of sanctioned vessels. Despite a persistent use of classic flagging nations like Panama, sanctioned Russian vessels are clearly also re-flagging to countries like Cameroon, Sierra Leone, Oman, Mozambique, and Azerbaijan. While we were unable to find very extensive patterns in ship age and tonnage among current flags in the data, we successfully confirmed that ships in this dark fleet are, on average, much older than the global average.

Declaration of Generative AI in writing

The authors declare that we have used Generative AI tools in the preparation of this manuscript. Specifically, the AI tools were utilized to write some of the scrapers and prepare the plots and tables as well as simple proof-reading (checking for typos and abbreviations), but not to generate scientific content, research data, or substantive conclusions. All intellectual and creative work, including the analysis and interpretation of data, is original and has been conducted by the authors without AI assistance.

Acknowledgements

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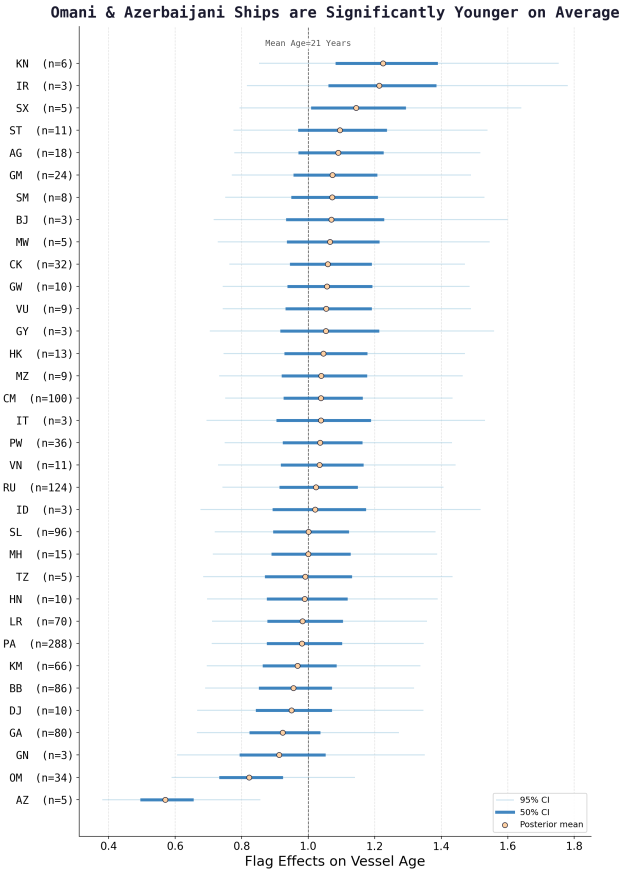

Figure B1. The effects on log tonnage in the Poisson model have been exponentiated to make them more interpretable.

Appendix A: Re-flagging Networks

Formally, we construct the re-flagging network using the following formula:

$$w(f_i, f_j) = \sum_{v \in V} \frac{\mathbf{1}[f_i \in F_v^-] \cdot \mathbf{1}[f_j \in F_v^+]}{|F_v^-| \cdot |F_v^+|} \quad \text{(A1)}$$

where f_i is the origin flag, f_j the destination flag, V is the set of vessels, F_v^- the set of past flags and F_v^+ the set of current flags for vessel v, and $\mathbf{1}[\cdot]$ is the indicator function. To avoid overweighting ships with many flags, we normalize.

To get a rough sense of flag transition dynamics, we calculate three scores for each country, with self-loops excluded. The sink and source scores capture how asymmetric a country's flag flows are, while the recycler score identifies countries with high throughput in both

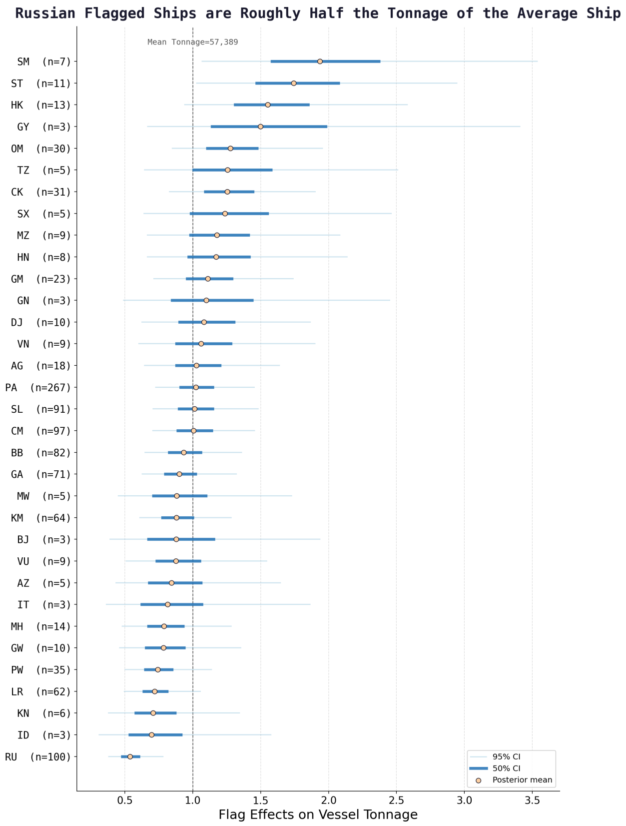

Figure B2. The outcome variable of log tonnage has been exponentiated to make it more interpretable.

directions:

$$\text{sink}(f) = \frac{w^+(f)}{w^-(f)+1} \tag{A2}$$

$$\text{source}(f) = \frac{w^-(f)}{w^+(f)+1} \tag{A3}$$

$$\text{recycler}(f) = \frac{w^+(f)+w^-(f)}{1+|w^+(f)-w^-(f)|} \tag{A4}$$

where

$$w^+(f) = \sum_{v\in V} \frac{\mathbf{1}[f \in F_v^+]}{|F_v^+|} \tag{A5}$$

$$w^-(f) = \sum_{v\in V} \frac{\mathbf{1}[f \in F_v^-]}{|F_v^-|} \tag{A6}$$

and the additive constant $+1$ in each denominator avoids division by zero. The recycler score is further restricted to countries where both $w^+(f)$ and $w^-(f)$ exceed a minimum threshold $\tau = 5$. Finally, we also calculate a “self-loop weight” to see which countries have used a flag previously and then used it again. The self-loop score is accumulated as follows:

$$\text{self-loop}(f) = \sum_{v\in V} \frac{\mathbf{1}[f \in F_v^- \cap F_v^+]}{|F_v^-|\cdot|F_v^+|} \tag{A7}$$

Having built the network, we explore the net flow of ships and tonnage to and from each flag. The net ship flow is

$$n_{\text{ships}}(f) = w^+(f) - w^-(f) \tag{A8}$$

and the net tonnage flow is

$$n_{\text{ton}}(f) = T^+(f) - T^-(f) \tag{A9}$$

where

$$T^+(f) = \sum_{v\in V} \frac{\mathbf{1}[f \in F_v^+]\cdot t_v}{|F_v^+|} \tag{A10}$$

$$T^-(f) = \sum_{v\in V} \frac{\mathbf{1}[f \in F_v^-]\cdot t_v}{|F_v^-|} \tag{A11}$$

and t_v is the tonnage of vessel v. To compare flags of different sizes, we also compute a normalized balance score:

$$b(f) = \frac{T^+(f)-T^-(f)}{T^+(f)+T^-(f)} \tag{A12}$$

which ranges from -1 (pure source) to 1 (pure sink).

Appendix B: Model Specs & Diagnostics

The Poisson model is specified in the following way:

$$\begin{aligned} a_v &\sim \text{Poisson}(\mu_v) \\ \log(\mu_v) &= \alpha + \beta_{F_v} \\ \beta_{F_v} &\sim \mathcal{N}(0,1) \\ \alpha &\sim \mathcal{N}(\log \bar{a}, 1) \end{aligned} \tag{B1}$$

where a_v is the age of vessel v in years, F_v its current flag, and $\bar{a}$ the empirical mean vessel age used to centre the intercept prior. β_{F_v} denotes the flag-level effect shared across both models.

Similarly, the linear regression with tonnage as dependent variable is defined as:

$$\begin{aligned} \log(t_v) &\sim \mathcal{N}(\mu_v, \sigma) \\ \mu_v &= \alpha + \beta_{F_v} \\ \beta_{F_v} &\sim \mathcal{N}(0,1) \\ \alpha &\sim \mathcal{N}(\overline{\log t}, 1) \\ \sigma &\sim \text{HalfNormal}(1) \end{aligned} \tag{B2}$$

where $\log(t_v)$ is the natural log of gross tonnage and $\overline{\log t}$ its empirical mean.

The model outcomes are discussed at length in the Results section, with detailed effects plots provided in Figure B1 and Figure B2. The highest R-hat value for the age model was 1.0247 and for the tonnage model 1.0173. Results were robust to models that added age and tonnage as controls.

Appendix C: IMO calculation

Formally, the IMO checksum is calculated as follows:

$$\sum_{i=1}^{6}(7-i)\cdot d_i \equiv d_7 \pmod{10} \tag{C1}$$

where $\mathbf{d} = (d_1, d_2, \ldots, d_7)$ is the sequence of digits of the IMO number. An IMO number is valid if and only if this congruence holds.

As noted in the Methods section, the IMO numbers in OpenSanctions data come from the sanctioning authorities, with additional details provided by external resources. In email correspondence with representatives from OpenSanctions, they pointed us to two datasets in particular: the Tokyo MoU Port State Control Inspections[5] and the Abuja MoU Port State Control Inspections.[6]

As noted, all ships in the data passed the IMO validation test. While we can entertain the idea that none of the ships used fake IMO numbers at any point, a real assessment of the validity of the IMO numbers reported by these ships would require an inspection of the Automatic Identification System (AIS) data that ships report within regular intervals while at sea.

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