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Plan of Action for the Management of Fleet Capacity in the IATTC:

PART II

Initial Allocation of PAES

NOAA Fisheries Southwest Fisheries Science Report to the Inter-American Tropical Tuna Commission

Executive Summary Part II.

A. Introduction to the Executive Summary

This Executive Summary on the initial allocation of Proportional Allowable Effort Shares (PAES) for this NOAA Fisheries Southwest Fisheries Science Report on the pilot Transferable Day Credit Scheme for the Inter-American Tropical Tuna Commission has three parts. The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author and do not necessarily reflect the views of U.S. NOAA Fisheries or the U.S. Department of Commerce.

The Executive Summary is organized as follows:

- Part A discusses the purposes of the analysis and the four different PAES allocation formulae.
- Part B gives a high-level summary of the analysis and the subsequent recommendation.
- Part C provides more detail on the analysis, but remains a high-level summary.
- Those readers only interested in the main results can read only Parts A and B of the Executive Summary.

The main report follows the Executive Summary. The main report contains considerable detail.

Thus, there are three levels of detail:

1. very little detail and "biggest picture" in Parts A and B of the Executive Summary,
2. additional detail in Part C of the Executive Summary, and

3. the main report for considerable detail.

Those readers interested in only the "big picture" and the major conclusions and recommendation can read only Parts A and B of this Executive Summary.

A.1. Purpose of Analysis and Four Different PAES Allocation Formulae

This report has five main purposes:

1. Develop four alternative formulae to allocate PAES through Contracting Parties to the Convention (CPCs) to their vessels active on the IATTC Regional Vessel Register

2. Evaluate each PAES allocation formula in terms of its equity in distribution among CPCs

3. Evaluate each PAES allocation formula in terms of economic efficiency gains due to the Transferable Days Credit Scheme. Gains in economic efficiency are measured by increases in daily vessel operating profit and revenue from before and after the scheme for each of the four different PAES formulae.

4. Evaluate the equity of distribution of daily vessel operating profit for each formula.

Very well-established equity and fair division principles (that have been expressed as mathematical formulae) provide a logical basis for choosing which type of PAES allocation is appropriate for this type of allocation issue. These principles are based upon the type of allocation problem as discussed below. Equity impact after the scheme is evaluated by well-established equity metrics from economics and information theory for each of the four formulae.

5. Recommend PAES allocation formulae based upon equity and fairness principles in designing the four PAES allocation formulae and efficiency and equity empirical analysis of the four PAES allocation formulae and the overall fishery due to the pilot Transferable Day Credit Scheme.

A.2. The four PAES allocation formulae are:

1. *Average 3 Years*: The historical Days formula Average 3 Years is the average of each vessel's Days over 2016-2018.

2. *Best X of Y*: The historical Days formula Best X of Y is each vessel's Days during 2014-2018 and chosen as:

3. *Days/m^3 of Capacity*: Days are directly proportional to a vessel's m^3 of capacity

4. *Hybrid* of *Best X of Y* and *Days/m^3 Capacity* or simply *Hybrid*: Vessels choose whichever is larger, Best X of Y Days or Days/m^3 of Capacity. This Hybrid fourth formula compromises between historical Days and Capacity for PAES.

All four PAES allocation formulae provide fair shares because of the IATTC decision-making process. CPCs with parity make decisions voluntarily and by consensus without imposition by a third party and according to their own valuations.

B. Summary and Final Results of PAES Allocation Analysis

B.1. Economic Efficiency: How is It Measured, Caveats, and Preamble

Economic efficiency and gains in economic efficiency (measured by increases in daily vessel operating profit and to a lesser extent daily vessel total revenue) due to the Scheme are understated because they only account for vessels increasing their profitability due to flexibility in scheduling their fishing operations throughout the year following the pilot Scheme (in the absence of a time-area closure) and do not include the potentially very large gains in economic efficiency due to reorganization of days among vessels in multi-vessel companies.

Vessel operating profit (total revenue minus operating costs) and total revenue are estimated on a daily rather than annual basis because two different data bases were used. Each data base leads to a different number of total days in a year for each vessel. Hence, even for the same daily vessel operating profit or daily vessel total revenue, annual vessel operating profit or annual vessel total revenue would differ depending upon the data base used for computation.

Vessel operating profit and vessel total revenue and their increases due to the pilot Transferable Day Credit Scheme were calculated only for vessels with at least 99 days in a year. Vessels with less than 99 days excluded US vessels making a single trip or other vessels with mechanical failures or part-time or other reasons for fishing less than 99 days in a year. Including such vessels (days < 99) leads to nonsensical results, since these vessels are qualitatively different and cannot be compared to vessels with at least 99 days in a year.

Gains in economic efficiency due to increased flexibility in fishing throughout the year following the pilot Scheme are measured by comparing the use of days by a vessel to a comparable best-practice vessel (comparable in vessel size, set type, and CPC Flag State, and measured by total catch per day) using a mathematical programming technique called Data Envelopment Analysis. Differences in economic efficiency between a vessel and its best-practice counterpart due to "skipper skill" (catch per day for factors other than use of days) are removed from the economic efficiency measure. Hence, the gains in economic efficiency are entirely due to increase flexibility in fishing following the pilot Scheme. The gains in economic efficiency are maximum possible gains.

These gains in economic efficiency due to the pilot Scheme exclude potential gains that can be enjoyed by multi-vessel companies. These companies can consolidate days on their most

efficient vessels as discussed next. Hence, gains in economic efficiency for multi-vessel companies are expected to be significantly larger than those reported in this analysis.

Simulated multi-vessel companies were developed by artificially constructed companies that can choose the optimum combination of days for each vessel (by CPC Flag State). The results indicate that multi-vessel companies can expect considerably larger gains in daily vessel operating profit. Vessels with negative vessel operating profit can transfer all or most of their days to other vessels (with positive profitability) within the company. Vessels with positive profitability lower than other vessels within the company can transfer some or all of their days to these more profitable vessels. Multi-vessel companies were constructed for each Flag State by randomly selecting vessels. The data do not allow identifying individual vessels or the companies to which they belong.

B.2. Demand for Landings and Imports in Ecuador and Implication for Price

An economic analysis of the demand for the landings and imports of yellowfin, bigeye, and skipjack in Ecuador shows that there are only very small increases in prices and revenues for landings in the months most favorable to vessels making landings. Imports constitute a large part of this market and serve to stabilize prices faced by vessels making landings. The analysis also shows that Bangkok remains the most important global tuna market by volume of landings for yellowfin, skipjack, and bigeye and takes the lead in setting global prices. Ecuador is now the second-most important global tuna market by landings and contributes to setting the global prices for yellowfin, skipjack, and bigeye.

B.3. Underlying Logical Basis of the PAES Allocation

Developing the underlying basis for the PAES allocation leads to very clear ways to allocate PAES allocation and eliminates many other ways to arrange the allocation. All division or allocation problems (not just in fisheries) follow a systematic pattern, from which this PAES allocation consciously and systematically draws.

The different ways to divide or allocate one or more “goods” (here days) depend upon several basic factors. The first is the number, nature, and types of “goods” to be divided. The second is establishing the underlying basis of eligibility of the claimants (here CPCs and their vessels). The third is the basis of the claimants’ claims to the different “goods” (here days). Claims can be based upon exogenous rights, precedent, compensation, reward, or fitness (efficiency). Allocation of PAES requires only establishing the eligible claimants (here CPCs and their vessels) according to membership in the IATTC and Resolution C-02-03) and the following exogenous right of the eligible claimants (the capacity of the CPCs and their vessels) and precedent (here historical days, which is not a right under Resolution C-02-03 or by the Transferable Day Credit Scheme).

All PAES allocation options are directly or indirectly based upon Resolution C-02-03 that establishes the eligible claimants (here CPCs of the IATTC and their vessels) and their resulting

exogenous right for capacity and the resulting precedent of historical days for each eligible CPC's vessels.

Many other logical bases of allocation are possible and considered, but they either: (1) are inconsistent with Resolution C-02-03 establishing which claimants (CPCs and their vessels) are eligible for capacity as an exogenous right and entitlement for a claim of PAES or precedent establishing historical days as the basis of the entitlement and claim for PAES or (2) violate the appropriate division principle of proportionality (when allocating or dividing a single homogenous "good" – here days and PAES – that is divisible, cardinally measured by a common metric -- 24 hours or calendar day – and that is robust to reallocation of days among vessels in multi-vessel companies).

There are other methods by which to allocate or divide "goods" but they are inappropriate for this type of "good" (days), the underlying basis for the PAES allocation (exogenous right of capacity and precedent of historical days), and robustness to reallocation of days among vessels in multi-vessel companies as discussed below.

B.4. Equity of PAES Allocation Formulae Themselves and the Overall Fishery Following the Scheme

Standard equity metrics from economics and information theory are used to evaluate the equity of the four different PAES allocation formulae and the resulting profitability of the entire purse seine fishery following the Scheme.

B.5. Recommendation

This report recommends, based upon this logical basis and empirical analysis for economic efficiency and equity of the four PAES allocation options, that either Option 2 or Option 4 be preferred:

- Option 2, the "*Best X of Y*" formula, since it would give greatest economic efficiency;

- Option 4, the "*Hybrid*" formula as a compromise between PAES allocation based upon historical days (*Best X of Y*) and well capacity in cubic meters (*Days/m^3 Capacity*).

- The equity differences between the four Options is slight. Hence, the recommendations are based upon economic efficiency (daily vessel operating profit) and the option that is most appropriate for the IATTC.

- All four Options are fair shares, i.e. fair PAES, since the IATTC decision-making is voluntary and by consensus by CPCs with parity without the decisions imposed by a third party

    - This is the technical definition of a fair bargain or fair share

Equity of daily vessel operating profit and total revenue (as outcomes of the Scheme) and allocated fair PAES, and thereby the state of distributive justice of the PAES allocation, are very close among all four PAES. Procedural justice is inherent to the process since all four allocation formulae are based upon the normative ethical principle, Aristotle's Equity Principle or proportionality, and because the process is fair (by the strict definition of how the decision-making is made). The recommendation can then be based upon economic efficiency and balancing competing ideas about the nature of claims (precedent through historical days or exogenous right through capacity due to Resolution C-02-03).

This study recommends either: (1) the *Best X of Y* PAES allocation scheme for greatest economic efficiency or (2) the *Hybrid* PAES allocation scheme as a compromise between PAES allocation based upon historical days (representing opportunity costs and precedent) and capacity (representing an exogenous right). (Days are not an exogenous right under Resolution C-02-03, nor does the Transferable Day Credit Scheme create days as a right.) The *Hybrid* PAES allocation scheme further allows compromise between competing types of claims (exogenous right of capacity or precedent of historical days) and claimants (different CPC Flag States and their vessels) and more directly draws upon Resolution C-02-03 (establishing the exogenous right) and the subsequent historical days as precedent

The Hybrid PAES option, which includes basing PAES upon capacity rather than historical days, readily accommodates two special classes of vessels:

1. most, but not all, US purse seine vessels that primarily fish in the Western and Central Pacific and only secondarily fish in the Eastern Pacific Ocean (a few US vessels are based in the Eastern Pacific Ocean) or

2. other purse seine vessels fishing less than 99 days.

As noted in Section I of this SWFSC Research Report, Resolution C-02-03 remains primary to the Transferable Day Credit Scheme, and thereby US purse seine vessels retain the option of a single trip to the Eastern Pacific Ocean from the Western and Central Pacific Ocean.

B.5. Equity-Efficiency Trade-Off for Daily Vessel Operating Profit

The following table and its accompanying figure summarize the equity-efficiency trade-offs between the four different PAES allocation formulae.

Conclusions on Equity-Daily Vessel Operating Profit Efficiency Trade-Off After the Scheme:

- *Best X of Y* is the most economically efficient and has the least equity.
- *Hybrid* is second most economically efficient and has the greatest equity.
- The differences in equity between different PAES formulae is very slight.

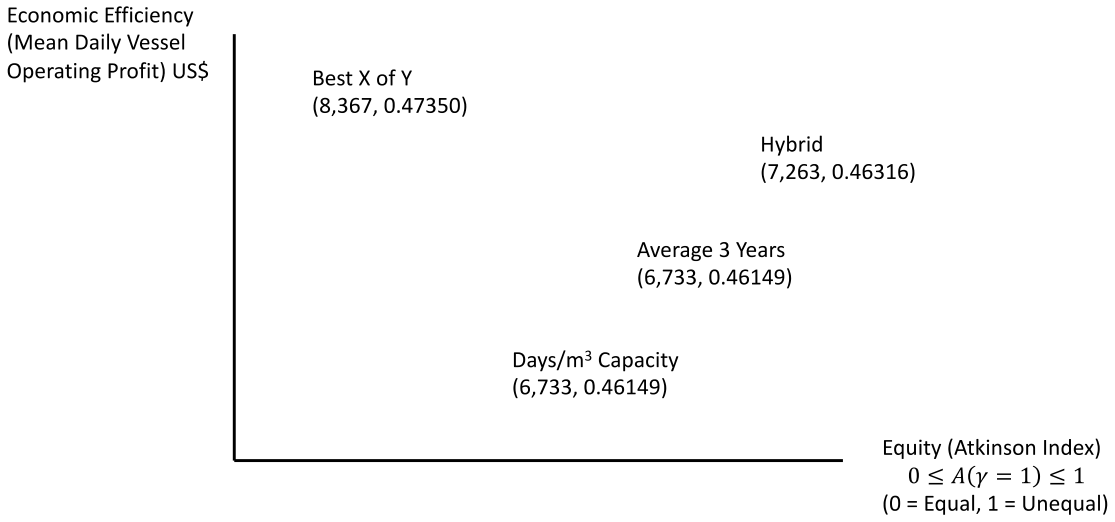
- *Hybrid* is fair on two accounts: once when the IATTC chooses a PAES formulae and second when vessels choose between *Best X of Y* and *Days/m³ Capacity*.

Table 5. Summary of Economic Efficiency and Equity by PAES Allocation Type

Type of PAES Allocation	Mean Daily Vessel Operating Profit (US$)	Rank of Profitability Highest to Lowest	Atkinson's Inequality Measure (γ=1)	Rank of Equality Highest to Lowest
Average 3 Years	7,097	3	0.43520	2
Best X of Y	8,367	1	0.47350	4
Days/m³ Capacity	6,733	4	0.46149	3
Hybrid	7,265	2	0.46316	1

Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. The results exclude gains in profit from reorganization within multi-vessel companies. *Average 3 Years* is calculated from different data than the other three PAES formulae Atkinson: Lower values more equal, $0 \leq A(\gamma = 1) \leq 1$.

Figure 26. Equity-Efficiency Trade-Off Among Vessels: Daily Vessel Operating Profit



B.6. Justice

As these empirical results make clear, distributive justice through equity of impact is clearly satisfied in the sense that any of the equity measures for the four allocation formulae are very, very close.

Procedural justice is satisfied given the nature of the IATTC decision-making process, which makes the allocated PAES fair shares, i.e. fair PAES.

The nature of the IATTC decision-making process and choice of allocation principle also establish justice as impartiality, an important concept of justice in the moral and political philosophy literature.

This procedural and distributive justice, along with justice as impartiality, is one approach to satisfying environmental justice.

C. Summary of More Detailed Conclusions

This section of the Executive Summary provides more detailed summary of the above but no new conclusions. The main body of the report below provides a still more detailed analysis. This section provides more detail on:

1. Allocation of PAES
2. Equity of Allocation of PAES
3. Economic Efficiency following the Scheme: Daily Vessel Operating Profit
4. Equity of impact following the Scheme: Daily Vessel Operating Profit
5. Economic Efficiency following the Scheme: Total Revenue
6. Equity of impact following the Scheme: Total Revenue

C.1. Caveats

In what follows, for the two historical days PAES formulae, often only *Best X of Y* is presented and not *Average 3 Years*, because *Best X of Y* provides greater economic efficiency (larger daily vessel operating profit per day) than *Average 3 Years* with only minimal differences in equity of distribution to CPCs and both are fair shares.

Economic efficiency per day rather than per year was selected because the methods of defining the allocation formulae gave data sets with different number of vessels and total days, i.e. different sample sizes, since the same number of vessels was not the same in the years 2014-2018 (used for Best X of Y) and 2016-2018 (used for Average 3 Years). Due to the advantages of Best X of Y over Average 3 Years, the other two PAES allocation formula, Days/m^3 Capacity and Hybrid, were developed using the same data as Best X of Y. A daily economic efficiency measure gives a more consistent and standardized efficiency metric.

Once a PAES formula has been selected, during each Management Year a vessel i receives an allocation of days through its Flag State CPC as follows (and discussed in Part I):

$$Days_i^* = PAES_i \; x \; TAE$$

where TAE denotes the Total Allowable Effort in nominal days that would be calculated by the IATTC.

C.2. Allocation of PAES

Conclusions on Allocation of PAES by CPC:

- Some Flag State CPCs display greater variation in mean PAES than others according to the type of PAES allocation formula. For example, El Salvador and the USA display considerable variation in mean PAES depending upon the formula, while Columbia and Peru display fairly stable mean PAES regardless of the formula.
- *Average 3 Days* and *Days/m^3 Capacity* favor El Salvador.
- *Average 3 Days* generally gives a higher mean PAES to most CPCs than *Best X of Y* and thereby greater operating profit for the entire purse seine fishery.
- *Days/m^3 Capacity* favors Spain, Guatemala, Mexico, Nicaragua, Panama, USA, and Venezuela plus DML holders.
- *Days/m^3 Capacity* is least favorable for Ecuador.
- *Hybrid* never dominates for a CPC except very slightly for Peru.

Conclusions on Allocation of PAES by Capacity Class and DML:

- Different PAES formulae favor different capacity classes in terms of mean PAES per vessel
- *Days/m^3 Capacity*: smaller capacity classes receive fewer days and larger capacity classes receive more days
- *Average 3 Years:* most of the time, gives the highest mean PAES by capacity class
- *Hybrid:* gives the third highest mean PAES for all capacity classes and DML or non-DML

Conclusions on How Rapidly Average 3 Years *and* Best X of Y *PAES are Allocated:*

- *Best X of Y more rapidly allocates smaller PAES than Average 3 Years but after about 50% of the PAES are allocated Average 3 Years more rapidly allocates PAES than Best X of Y.*

Conclusions on How Rapidly PAES are Allocated:

- Even though *Hybrid* blends *Best X of Y* and *Days/m^3 Capacity*, *Hybrid* allocates PAES very similar to *Best X of Y*
    - Best X of Y dominates the most favorable PAES allocation for most vessels and CPCs
- *Days/m^3 Capacity* allocates PAES very differently than *Best X of Y* or *Hybrid*
- A larger proportion of the smaller PAES are more quickly allocated with *Hybrid*, followed by *Best X of Y* until about 20% of the shares have been allocated, and then reversing with slightly faster *Best X of Y* allocation.
- Both *Best of Y* and Hybrid reach a fairly constant PAES of about 0.04 by 40% of all PAES have been allocated, and then the size of the allocated PAES rising more slowly thereafter, with *Best X of Y* reaching larger PAES.
- *One Day/m^3 of Capacity* shows more inequality in PAES size, with fewer smaller PAES and larger frequency of larger PAES, more slowly reaching equality with *Best X of Y* and *Hybrid* at about 45% of all PAES allocated and rapidly diverging with its larger PAES thereafter.

Conclusions on the Frequency Distribution of Allocated PAES by Vessel:

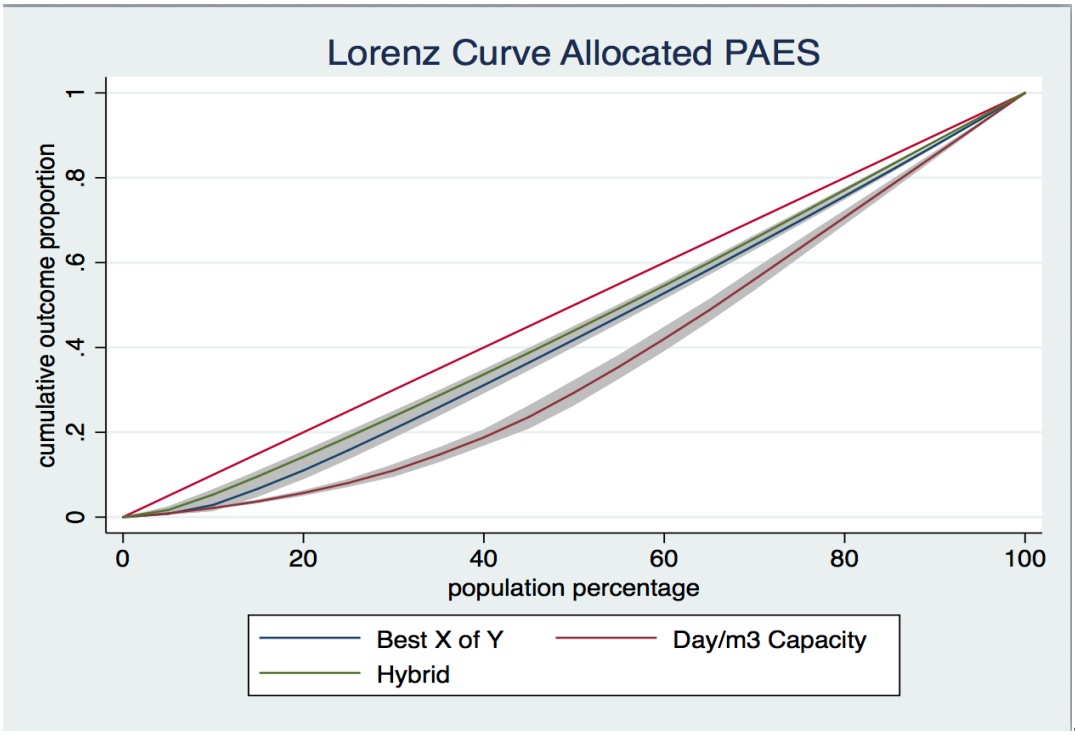
- All methods of allocating PAES give a wide range between smallest and largest allocated PAES
- *Best X of Y* and *Hybrid* are very similar compared to *Days/m^3 Capacity*

C.3. Equity of Allocation of PAES

Conclusions on the Equity of Allocation of PAES:

- All four alternative ways to allocate PAES give a high degree of equity according to standard equity metrics.
- *Best X of Y, Average 3 Years*, and *Hybrid* PAES allocation have very close measures of equity according to standard equity metrics (due to their basis, in whole or part, upon historical days).
- The ranking in equity from highest equity to lowest equity is:
    - *Hybrid > Best X of Y > Average 3 Years > Days/m^3 Capacity*

Figure 12. Lorenz Curve for Allocated PAES *Best X of Y, Days/m^3 Capacity*, and *Hybrid*



Note: No restrictions on vessels' days. All calculations from same data
Diagonal line is perfect equity. Closer to (farther from) diagonal line indicates greater (lesser equity).

Table 2. Equity Metrics for Different PAES

Type of PAES Allocation	Gini Coefficient	Ratio of 90th Percentile to 10th Percentile	Theil's Generalized Entropy GE(1)	Atkinson's Inequality Measure (γ=1)
Average 3 Years	0.16258	1.209	0.06225	0.08958
Best X of Y	0.12636	1.782	0.04937	0.07679
Days/m³ Capacity	0.26022	5.151	0.13042	0.15962
Hybrid	0.08827	1.397	0.02379	0.03476

No restrictions on number of days per vessel.
Average 3 Years is calculated from different data than the other three PAES formulae
Atkinson: Lower values more equal, $0 \leq A(\gamma = 1) \leq 1$. Atkinson can be interpreted as the percentage of per capita "income" (here daily vessel operating profit per vessel) that would provide the same total welfare as the actual "income" if it were equally distributed.
Gini Coefficient: Lower values more equal, $0 \leq G \leq 1$.
Theil's Generalized Entropy: Lower values more equal, $0 \leq GE(1) \leq \infty$.

C.4. Economic Efficiency Due to the Scheme: Daily Vessel Operating Profit

Conclusions on Economic Efficiency Due to the Scheme Measured by Daily Vessel Operating Profit:

The maximum economic efficiency, measured by daily vessel operating profit, results when comparing before and after the scheme when ranked from highest to lowest are:

- *Best X of Y > Average 3 Years > Hybrid > Days/m^3 Capacity*
- Some vessels displayed negative vessel daily vessel operating profit before the transferable day credit scheme.
- Some, but fewer, vessels still displayed negative albeit lower daily vessel operating profit after the scheme.
- Some highest-performing vessels' daily vessel operating profit remains unchanged even after the transferable day credit scheme, since these vessels are already optimally performing.
- The reported changes in daily vessel operating profit following the transferable day credit scheme are due to improved vessel operations from more flexible fishing (with constant prices).
- The results exclude gains in profit from reorganization within multi-vessel companies.
    - Further research for simulated multi-vessel companies, whereby companies can choose the optimum combination of days for each vessel, indicates that multi-vessel companies can expect considerably larger gains in daily vessel operating profit.

Table 3. Summary Statistics Daily Vessel Operating Profit ($)

Type of PAES Allocation	Mean	Standard Deviation
Before:		
Average 3 Years	5,036	10,008
Best X of Y	5,843	8,931
Days/m^3 Capacity	5,843	8,931
Hybrid	5,843	8,931
After:		
Average 3 Years	7,097	11,365
Best X of Y	8,367	11,488
Days/m^3 Capacity	6,733	9,750
Hybrid	7,263	9,897

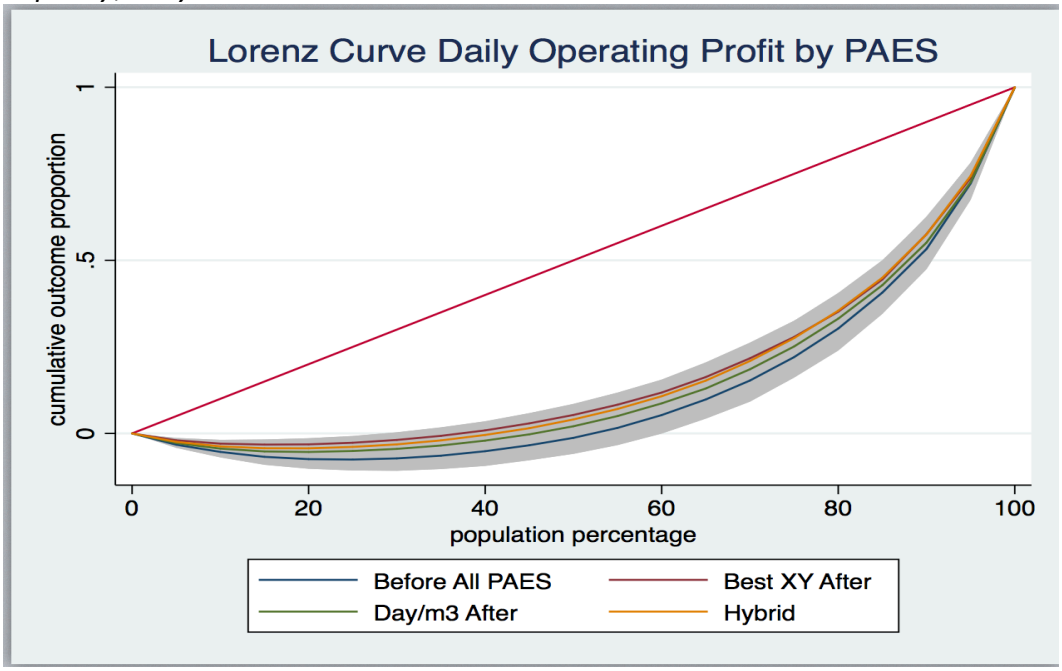
Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results.
Average 3 Years calculated from different data than the other PAES allocation formulae.
Differences calculated directly from individual vessel observations.
Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

C.5. Equity: Daily Vessel Operating Profit

Conclusions on Equity of Daily Vessel Operating Profit Distributed Among Individual Vessels:

- All four alternative ways to allocate PAES give a high degree of equity according to standard equity metrics.
- The ranking in equity from highest equity to lowest equity is: *Hybrid* > *Best X of Y* > *Average 3 Years* > *Days/m³ Capacity*
- The differences between different PAES formulae are statistically significant but very slight
- There is less equity across all vessels and States than for total revenue, i.e. vessel daily operating profit is less equitably distributed across all vessels and States than total revenue, reflecting differences in vessel daily operating costs
- Equity in daily vessel operating profit is lower than the equity PAES allocation according to standard equity metrics.

Figure 25. Lorenz Curve Daily Vessel Operating Profit: Before All PAES, *Best X of Y*, *Days/m³ Capacity*, & *Hybrid*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. The results exclude gains in profit from reorganization within multi-vessel companies.

Table 5. Equity Metrics for Vessel Operating Profit with Different PAES

Type of PAES Allocation	Gini Coefficient	Ratio of 90th Percentile to 10th Percentile	Theil's Generalized Entropy GE(1)	Atkinson's Inequality Measure (γ=1)
Before PAES Allocation and Scheme	0.52894	28.424	0.47446	0.46828
After Scheme				
Average 3 Years	0.51651	19.419	0.45094	0.43520
Best X of Y	0.53698	25.323	0.49293	0.47350
Days/m^3 Capacity	0.53586	26.913	0.48782	0.46149
Hybrid	0.52724	24.092	0.46988	0.46316

Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. The results exclude gains in profit from reorganization within multi-vessel companies.
Average 3 Years is calculated from different data than the other three PAES formulae
Atkinson: Lower values more equal, $0 \leq A(\gamma = 1) \leq 1$. Atkinson can be interpreted as the percentage of per capita "income" (here daily vessel operating profit per vessel) that would provide the same total welfare as the actual "income" if it were equally distributed.
Gini Coefficient: Lower values more equal, $0 \leq G \leq 1$.
Theil's Generalized Entropy: Lower values more equal, $0 \leq GE(1) \leq \infty$.

Table 6. Summary of Economic Efficiency and Equity Following the Scheme by PAES Allocation Type

Type of PAES Allocation	Mean Daily Vessel Operating Profit (US$)	Rank of Profitability Highest to Lowest	Atkinson's Inequality Measure (γ=1)	Rank of Equality Highest to Lowest
Average 3 Years	7,097	3	0.43520	2
Best X of Y	8,367	2	0.47350	4
Days/m^3 Capacity	6,733	4	0.46149	3
Hybrid	7,265	1	0.46316	1

Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. The results exclude gains in profit from reorganization within multi-vessel companies.
Average 3 Years is calculated from different data than the other three PAES formulae

Atkinson: Lower values more equal, $0 \leq A(\gamma = 1) \leq 1$. Atkinson can be interpreted as the percentage of per capita "income" (here daily vessel operating profit per vessel) that would provide the same total welfare as the actual "income" if it were equally distributed.

Conclusions for Mean Daily Vessel Operating Profit Before and After: *Best X of Y, Days/m3 Capacity* and *Hybrid:*

- All categories increase daily vessel operating profit due to the Scheme.
- Capacity Classes 3-4 and 5 have relatively small mean daily operating profit, with Capacity Class 5 facing negative profit prior to the Scheme.
- Capacity Class 6 DML vessels have lower mean daily vessel operating profit than Capacity Class 6 without DML vessels
    - Could potentially be due to lower ex-vessel transfer prices in vertically integrated seafood companies.
- Capacity 6 vessels without DMLs enjoy the highest mean profitability.
- *Best X of Y, Days/3 Capacity*, and *Hybrid* all have very similar impacts upon increased profitability for Class 4-5 and Class 5 vessels.
- For Class 6 vessels, with and without DMLs, the order of increased profitability due to the Scheme from highest to lowest is: *Best X of Y* > *Hybrid* > *Days/m^3 Capacity*.

Conclusions for Mean Daily Vessel Operating Profit Before and After the Scheme by CPC: *Best X of Y*, *Days/m^3 Capacity* and *Hybrid:*

- The level of profit varies by CPC, with the vessels of some CPCs enjoying larger profits than the vessels of other CPCs.
- All CPCs enjoy an increase in profitability under the Scheme for all four alternative PAES allocation methods with the exception of the USA that loses profitability for Best X of Y.
    - That is, the USA due to its unique arrange for vessel trips from the Western and Central Pacific loses profitability for a PAES allocation based upon historical days.
- Some CPCs gain in mean daily vessel operating profit more than others due to the Scheme
- The results exclude gains in profit from reorganization within multi-vessel companies.

C.6. Economic Efficiency Due to the Scheme: Daily Vessel Total Revenue

Conclusions:

- Highest daily vessel total revenue after Scheme ranked from highest to lowest:
    - *Best X of Y > Average 3 Years > Hybrid > Days/m3 Capacity*
- Highest percent gain in daily total revenue due to Scheme ranked from highest to lowest:
    - *Best X of Y > Average 3 Years > Hybrid > Days/m3 Capacity*

Table 7. Summary Statistics Daily Vessel Total Revenue ($)

Type of PAES Allocation	Mean	Standard Deviation
Before:		
Average 3 Years	19,933	10,969
Best X of Y	20,534	10,1967
Days/m^3 Capacity	20,534	10,1967
Hybrid	20,534	10,1967
After:		
Average 3 Years	22,003	12,293
Best X of Y	23,058	12,495
Days/m^3 Capacity	21,424	10,789
Hybrid	21,954	10,900
% Gain		
Average 3 Years	11.02	0.1852249
Best X of Y	14.58	0.3996459
Days/m^3 Capacity	6.52	0.3068319
Hybrid	9.95	0.3527731

Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. *Average 3 Years* calculated from different data than the other PAES allocation formulae. Differences calculated directly from individual vessel observations.

C.7. Equity Following the Scheme: Daily Vessel Total Revenue

Conclusions on Equity of Daily Vessel Total Revenue by PAES Allocation Type

- Daily vessel total revenue is distributed with greater equity among vessels than is daily vessel operating profit (as indicated by the value of equity metrics)
- Ranked in terms of most equity to least equity:
  - *Hybrid > Days/m3 Capacity > Best X of Y > Average 3 Years*

Main Body of the Report

The balance of this report is the main body that provides much more detailed analysis of the summary presented above. To reiterate, Parts A and B of the Executive Summary provide sufficient information for the recommendation and Part C of the Executive Summary provides further detail. The main body of the report gives considerable detail, and can be skipped by those readers interested only in the "big picture".

Organization of Part II

Tables in Part II

Figures in Part II

1. Introduction

1.1. Purpose of the Analysis

This analysis:

1. develops the logical basis of the eligibility of claimants and their entitlements and claims for PAES,
2. properties of PAES allocations,
3. develops four alternative formulae to allocate Proportional Allowable Effort Shares (PAES) to vessels active on the IATTC Regional Vessel Register,
4. evaluates each PAES allocation formula in terms of its equity in distribution among Contracting Party to the Convention (CPCs),
5. evaluates each PAES allocation formula in terms of gains in daily vessel operating profit (economic efficiency) due to the transferable days credit scheme, and
6. for each formula evaluates the equity of distribution of daily vessel operating profit.

Gains in economic efficiency are measured by increases in daily vessel operating profit and total revenue from before and after the scheme for each of the four different PAES formulae. Very well-established equity and fairness principles are not used for the sake of equity per se but to provide a logical basis for choosing which type of PAES allocation is appropriate for this type of allocation system. Equity impact after the scheme is evaluated by well-established equity metrics from economics and information theory for each of the four formulae.

The role of the analysis includes clearly laying out the basis of the assumptions implicitly underpinning the four PAES allocation formulae, and to explore their logical and empirical consequences. There is an enormous amount of analysis and literature on allocations for many industries, stretching back thousands of years. This analysis draws upon this previous experience rather than "reinventing the wheel". The balance of Section 1 lays out the logical basis and rationale for the allocation based upon this extensive experience.

Those readers solely interested in the analysis and empirical results can skip the rest of Section 1, and jump immediately to Section 2.

1.2. Basis of the Allocation

The proposed allocation is based upon the following *eligibility criteria*:

- A State should be a Contracting Party to the IATTC Convention (hereafter CPC)
- A CPC's exogenous rights to capacity established by Resolution C-02-03
- A CPC's vessels active on the IATTC Regional Vessel Register

Distributed PAES are claims, and claims require a justification. PAES claims are justified on the basis of exogenous rights and precedent.[1] Exogenous rights are exogenous to the allocation of PAES and the process of fishing. First consider exogenous rights and then precedent.

[1] Other widely used bases for claims are compensation, reward, or fitness (efficiency). None of these are relevant here.

Exogenous rights justify and provide a basis for entitlement, claims, and allocation. With equal exogenous rights, differences in the claims is the only reason to give different PAES to the CPCs and their vessels (the claimants). Equal exogenous rights correspond to equality *ex ante* in the sense of an equal claim to the days to be distributed. This stands in contrast with equality *ex post* (which will be evaluated by standard equity metrics).

A PAES allocation has to consider two exogenous rights and accompanying entitlements and claims. The first exogenous right is the legal, formal rights of States-Parties as Flag States under international law and as CPCs to the IATTC. The second exogenous right is capacity established by Resolution C-02-03.

Precedent can also justify entitlement and claims and thereby provide a basis for defining and allocating PAES. Precedent establishes what is normal, customary, and expected. Precedent may not be as strong as formal exogenous rights for the basis of entitlements and claims, but precedent is still widely used by humanity over thousands of years and many different types of division and allocation cases.

Precedent is formed by historical days of eligible vessels. Historical days are not exogenous rights with accompanying claims, since the IATTC through Resolution C-02-03 or other means, or will through this pilot Transferable Day Credit Scheme, has not established historical days as a right. Instead, historical days reflect historical patterns of activity and establish precedent for PAES. Moreover, the pilot Transferable Day Credit Scheme is a credit system in which a vessel's days are a limit and not a property right. The credit system does not establish an exogenous right and accompanying claim by Flag States or vessels for days.

To summarize to this point, eligible CPCs have exogenous rights to capacity established by Resolution C-02-03 and vessels active on the Regional Vessel Register are eligible to receive PAES. PAES will be established on the basis of the exogenous right to capacity and precedent in the form of historical days for eligible vessels.

Vessel operating profit per day rather than per year was selected to measure economic efficiency because the methods of defining the allocation formulae give data sets with different number of vessels and total days. That is, the different allocation formulae have different sample sizes, since the same number of vessels do not appear in the same in the years 2014-2018 and 2016-2018 used to calculate the different allocation formulae. In sum, a daily rather than annual economic efficiency measure gives a more consistent and standardized efficiency metric.[2]

1.3. Equity and Fairness

[2] Multiplying daily vessel operating profit by different TAE to give annual daily vessel operating profit does not qualitatively change the overall results of this analysis. That is, the conclusions hold for annual as well as daily vessel operating profit for the entire fleet.

A request to consider equity was incorporated into the analysis.[3] The closely related concept of fair division was also incorporated into the analysis to provide a more comprehensive analysis. The resulting analysis develops PAES allocation formulae through a process that has equity and fair division, giving process justice, and outcomes, giving distributive justice. Use of equity and fair division principles (which includes economic efficiency). establish a plausible and justifiable basis for agreement that narrows the bargaining range to coordinate and legitimate expectations that shape the allocation formulae. This approach narrows down alternatives on the basis of rational principles. Empirical equity metrics and economic efficiency models quantitatively *ex-post* evaluate alternative distributions for distributive justice and economic efficiency.

Proportionality (Aristotle's Equity Principle) states that a "good" – here TAE and days -- should be divided in proportion to the differences of the claimants – here CPCs and their vessels' capacity and historical days. The TAE and days should be homogeneous (24 hours in the Scheme), divisible, and measured by a common metric, which here is day as defined in Section I.

Equity of the distribution is implemented by the use of proportionality to divide the TAE through PAES among the CPCs and their vessels and by evaluating the equity of the PAES distribution among the CPCs and their vessels by standard equity metrics.

The PAES are a *fair share* because they are allocated based upon IATTC CPCs with parity that voluntarily make decisions through consensus without a third party making or imposing the decision. Due to the nature of this impartial decision-making and procedure, these allocation rules should be *envy-free*, which gives another way to give fair PAES. (The PAES allocation is envy-free in that no CPC or vessel prefers another's PAES allocation to its own due to the nature of the PAES allocation procedural decision-making and the claimants and their claims are equal since compensation, reward, or fitness serve as the basis of the allocation.)

1.4. Properties and Features of the PAES Allocation

The four PAES allocation formulae developed below satisfy a number of desirable properties. This discussion can be easily skipped by readers interested only in the empirical results without any loss in understanding.

The PAES allocation is *economically efficient* by the standard economics definition of Pareto efficiency in that more PAES to one CPC or vessel requires less for another CPC or vessel.

[3] Equity in this analysis is not meant to pertain to social justice of "society" or the international order, but to the equity of the IATTC PAES allocation process, i.e. to equity "in the small" rather than equity "in the large" or "local justice" rather than "broad global social justice". Suffice it to say at this point that there is no single overarching definition of equity, that equity depends upon the context of the issue at hand, and that equity does not necessarily mean "ethical" or "moral" but what the IATTC (and its CPCs) considers appropriate for its needs.

The PAES allocation is *impartial*, since equally entitled CPCs and vessels are treated alike in the IATTC.

The PAES allocation rule *is robust to transfer of verifiable days* because it is not subject to manipulation and the subsequent distortion of incentives in what is called collusion-proof. Multi-vessel companies are likely to transfer PAES from their less efficient vessels to their more efficient vessels. When PAES / days are transferred, this transfer effectively merges the PAES into a single PAES or splits the PAES up into multiple PAES. Whether PAES are consolidated or divided, the total PAES allocated to the multi-vessel company should remain the same. A simple numerical example is as follows. Suppose the TAE is 1,000 days and a multi-vessel company with two vessels receives 200 days for vessel A (PAES = 0.2 = 200/1,000) and 100 days for a less efficient vessel B (PAES = 0.1 = 100/1,000) and total company is PAES = 300/1,000 = 0.3. If all days are transferred from B to A, total company PAES remains at 0.3.

The PAES allocation rules should be *acceptable* to CPCs: a vessel's operating profits after assessment cannot be worse-off than before the Scheme given a TAE i.e. a vessel's operating profit after the PAES must be greater than or equal to its stand-alone opportunity cost of operating profit prior to the Scheme, given a TAE. These stand-alone opportunity costs, by excluding PAES allocation rules or limiting the range of potential PAES allocation rules, delimit the range of plausible agreement by CPCs. All vessels and CPCs in the aggregate gain and no individual CPC or vessel loses daily vessel operating profit. No vessel or CPC should be penalized for joining the cooperative scheme. In short, any rational PAES allocation rule should ensure that CPCs and vessels, individually and by groups, at least cover their stand-alone opportunity costs and thus be acceptable given a TAE. Thus, these CPCs and their vessels are *individually rational* and *collectively rational*.

The PAES allocation rules are *consistent* in that every two claimants – CPCs and vessels – divided the TAE into PAES as they would if they were the only two claimants. A distribution which is fair for the IATTC as a whole should also be fair from the standpoint of every subgroup (CPC, company, capacity class, DML holder or not, method of fishing) within the IATTC.

The PAES allocation formulae satisfy *parity* in that there is no priority of one CPC or vessel in the PAES allocation other than on the basis of the exogenous right of capacity and precedent of historical days.

The PAES allocation formulae are *appropriate* in that they are shaped partly by principle, partly by precedent, and partly by what can be practicably implement. Appropriateness expresses what the IATTC deems reasonable and customary in this sharing situation.

1.5. Summary of Salient Factors in the PAES Allocations

In sum, the salient factors and features in the PAES allocations are:

- Eligibility
    - A State should be a Contracting Party to the IATTC Convention
    - Exogenous rights of capacity established by Resolution C-02-03
    - Vessels active on the IATTC Regional Vessel Register
- Exogenous Rights
    - Capacity granted to CPCs through Resolution C-02-03 (forming an exogenous right)
- Precedent
    - Historical days of eligible vessels (forming precedent)
- Nature of the "good" to be distributed – days
    - A single, homogeneous, divisible, cardinally measured by a common metric, desirable to have, and deterministic
    - Versus multiple goods or undesirable "bads" that are heterogenous, ordinal, not measured by a common metric, not desirable to have (e.g. bycatch), and stochastic
- Choice of principles for initial allocation
    - Proportionality (single homogeneous, divisible, good – days – that are cardinally measurable by a common metric)
    - Aristotle's Equity Principle
    - Robust to transfer of days among vessels
- Equity of PAES allocation and distribution of daily vessel operating profit or total revenue to CPCs and their vessels (as measured by equity metrics)
- Economic efficiency of the initial PAES allocation measured by daily vessel operating profit
- Fair PAES (CPC voluntary and consensual decision-making without third party making decision, also makes PAES allocation envy-free)
- Impartiality (equally entitled CPCs and vessels are treated alike in the IATTC)
- Collusion-proof (PAES allocations are robust to transfer of PAES within multi-vessel companies)
- Acceptability (a vessel's operating profits after assessment cannot be worse off than before the Scheme given a TAE, i.e. a vessel's operating profits after the Scheme must be greater than or equal to before the Scheme).
- Consistency (Every two claimants – CPCs and vessels – divide the TAE into PAES as they would if they were the only two claimants.)
- Parity (there is no priority of one CPC or vessel in the PAES allocation given capacity and historical days)
- Appropriateness (expresses what the IATTC deems reasonable and customary in this sharing situation).
- Potentially size of vessel (capacity) and whether DML or not

1.6. Definitions of Terms in Transferable Day Credit Scheme

The following definitions were previously presented and are used here:

- *Day*: Any calendar day, or part of a calendar day, in a Management Year during with a purse seine vessel is in the waters under the jurisdiction of the IATTC outside of a port. Days are not a fraction of a day (e.g. 18 hours rather than 24 hours).
- *Total Allowable Effort (TAE):* Total nominal days for a Management Year.
- *Proportional Allowable Effort Share (PAES):* CPC's proportion (share) of Total Allowable Effort which in turn is allocated to individual vessels also on the same proportional basis
- *Party Allowable Effort (PAE):* Allowed days in Management Year based upon PAES and TAE
- *Management Year*:
- *Credit*: Unused portion of a vessel's Allowable Effort during a Management Year.
- *Capacity*: m^3 of purse seine vessel well capacity active on the IATTC Regional Vessel Register.

2. General Formulae for the PAES

The first step in the implementation of the pilot Scheme is to calculate each vessel's PAES. The allocation of the PAES is first to the eligible CPC and then by the respective CPC to each eligible individual vessel.

As established above, the PAES can be calculated based upon CPCs' vessels' historical days, a vessel's days per m^3 of capacity, or a hybrid of a vessel's historical days (*Best X of Y*) and *Days/m^3 of Capacity* for purse seine vessels that are active on the Regional Vessel Register. (The hybrid is created by each CPC and its vessels fairly selecting either historical days (*Best X of Y*) or *Days/m3 of Capacity* as the basis of their PAES allocation.

Days from multiple years are averaged across the years to smooth out systematic and random variations, such as mechanical breakdown, transfer of ownership, weather, biomass fluctuations, etc. Specifically, four options or formulas to calculate the PAES are considered:

Option 1: **Average 3 Years**: The historical Days formula Average 3 Years is the average of each vessel's Days over 2016-2018.

Option 2: **Best X of Y**: The historical Days formula Best X of Y is each vessel's Days during 2014-2018 and chosen as:

a. Out of the most recent 5-year effort history, each vessel is allocated an average of its best 3 years of effort out of the most recent 5 years the vessel has been active on the regional vessel register.
b. The average 3 out of the most recent 4 years of effort if a vessel has only been active on the regional vessel register 4 out of the past 5 years.

c. The average 2 out of the most recent 3 years of effort if a vessel has only been active on the regional vessel register 3 out of the past 5 years.
d. The average 1 out of the most recent 2 years of effort if a vessel has only been active on the regional vessel register 2 out of the past 5 years.
e. A vessel active on the regional vessel register for 1 out of the past 5 years receives its effort for that one year.

Option 3: **Days/m^3 of Capacity**: Days are directly proportional to a vessel's m^3 of capacity

Option 4: **Hybrid of Best X of Y and Days/m^3 Capacity** or simply **Hybrid** lets vessels choose whichever is larger, Best X of Y Days or Days directly proportional to vessel m^3 of Capacity. This Hybrid fourth formula compromises between historical Days and Capacity for PAES.

Using updated data, the method of analysis is the same as previously used to analyze gains in economic efficiency reported in "Plan of Action for the Management of Fleet Capacity", April 2019 in La Jolla CA, USA and July 2019 in Bilbao, Spain.[4] Later years of data are not used due to the unusual fishing patterns that arose due to Covid-19. The analysis can be subsequently updated with more recent data when the fishery returns to more established patterns.

3. Four Alternative Formulae for PAES

Vessel historical Days PAES are calculated as follows, where the two different definitions of historical days used to calculate PAES give two versions of the following formula:[5]
The following formulae can be differentiated by vessel capacity class, holding of DML or not, or any other suitable criteria.

$$S_i = \frac{Days_i}{\sum_{i=1}^{N} Days_i} = Proportional\ Allowable\ Effort\ Share\ (PAES)$$

Where:

$$i = Vessel\ i$$

[4] Report prepared to satisfy the contract to the IATTC, entitled "Action Plan for Fleet Capacity Management in the IATTC", funded by the Directorate General for Maritime Affairs and Fisheries of the Commission of the European Union and directed by Dr. Dale Squires. Distributed 05 April 2019, Ref: 0170-410 and presented to "Workshop to analyze the technical document prepared by the consultant for the development of a fleet capacity management plan and associated measures" held in La Jolla on 23-25 April 2019 as notified by memorandum Ref. 0120-410 dated 20 March 2019. The report was a follow-up to the presentation made to the Commission in August 2018. See also "New Alternatives for Capacity Management" presented to the 21st Permanent Working Group on Fleet Capacity July 20 2019 and 94th Meeting of the IATTC, Bilbao, Spain. Available at: XXX

[5] Any of these PAES allocation formulae are economically efficient (what is called Pareto optimal), since one CPC's PAES increases only when another CPC's PAES decreases and none is thrown away. The economic efficiency of the PAES allocation differs from the economic efficiency impact upon individual vessels' performance once they receive the PAES allocation. The vessel's economic efficiency after receiving its PAES is evaluated in terms of daily vessel operating profit.

$$Days_i = Vessel\ i's\ historical\ days\ as\ the\ measure\ of\ effort$$

$$N = number\ of\ vessels$$

$$0 < S_i < 1, \sum_{i=1}^{N} S_i = 1$$

Vessel *i*'s Allowable Effort in Management Year = $S_i * Total\ Allowable\ Effort$

The historical days formula *Average 3 Years* is each vessel's day averaged over 2016-2018.

The historical days formula *Best X of Y* is each vessel's days chosen as:

Out of the most recent 5-year effort history, each vessel is allocated an average of its best 3 years of effort out of the most recent 5 years the vessel has been active on the regional vessel register:

a) The average 3 out of the most recent 4 years of effort if a vessel has only been active on the regional vessel register 4 out of the past 5 years.
b) The average 2 out of the most recent 3 years of effort if a vessel has only been active on the regional vessel register 3 out of the past 5 years.
c) The average 1 out of the most recent 2 years of effort if a vessel has only been active on the regional vessel register 2 out of the past 5 years.
d) A vessel active on the regional vessel register for 1 out of the past 5 years receives its effort for that one year.

PAES based upon vessel historical capacity, called *Days per m³ of Capacity*, are calculated in a similar manner:

$S_i = \frac{Capacity_i}{\sum_{i=1}^{N} Capacity_i}$, where:

$Capacity_i =$ purse seine vessel i's historical capacity measured in m³ of well capacity for vessels on the Regional Vessel Register.

The resulting days from this application can be called *Days-Capacity*.

The *Hybrid PAES*, which represent a compromise and blend of historical days and capacity, is calculated as follows. Each vessel i is assigned one of the following days-hybrid:

$$Days_i - Hybrid_i = Days_i\ if\ Days_i > Days_i - Capacity_i$$

$$Days_i - Hybrid_i = Days_i - Capacity_i \; if \; Days_i < Days_i - Capacity_i$$

This assignment gives each vessel its most favorable allocation of days depending upon whether $Days_i$ is larger or smaller than $Days_i - Capacity_i$.

Once this assignment has been made, then *Hybrid PAES* are calculated as follows:

$$S_i = PAES_i = \frac{Days_i - Hybrid_i}{\sum_{i=1}^{N} Days_i - Hybrid_i}$$

Vessels were allowed a maximum of 300 $Days_i - Hybrid_i$.

This approach allows vessels to choose either $Days$ or $Days_i$ or $Days_i - Hybrid_i$ based upon their own best interests, rather than imposed by a third party, giving fair division and a fair process and fair bargain[6]. In addition, neither weights for historical days and capacity or a weighting formula are required, circumventing the difficult decision about the most appropriate weight.

Two other possible formulae, which are rejected as inconsistent with the exogenous rights and precedent of historical days, are even division by CPC or by vessel. Even division by CPC is: $S_i = \frac{1}{N}$, where N denotes the number of eligible CPCs. Even division by vessel is $S_i = \frac{1}{N}$, where N denotes the number of eligible vessels.

Once a PAES formula has been selected, during each Management Year a vessel i receives an allocation of days through its Flag State CPC as follows:

$$Days_i^* = PAES_i \; x \; TAE$$

4. Worked Example of PAES

The following provides a worked example of the PAES allocation formula. Supposed a vessel averaged 200 days per year over the three years of 2016-2018 and that the Total Allowable Effort (TAE) in a Management Year was calculated to be 47,000 nominal days. The vessel's CPC then would receive a PAES of:

[6] Such an approach may also satisfy another well-known fairness criterion, no-envy, at least from a certain perspective. An envy-free distribution occurs if no claimant prefers another's portion of a particular allocation of a "good" to one's own. Envy-free distribution requires divisible "goods" and parties with equal claims. Here, the claims are equal in the sense that when the unit is day or m^3 of well capacity are equal among claimants (vessels and Flag States) although the total holdings by each vessel when differentiated by days or m3 of well capacity are not equal.

$$S_i = \frac{200}{45{,}000} = 0.00444$$

Each year over a Resolution cycle, multiply the PAES = 0.00444 by that year's TAE to give the Allowable Effort. Thus, the CPC's Allowable Effort is:

$$0.00444 * 47{,}000 = 208.68,$$

which when rounded gives 209 days of Allowable Effort for a CPC's vessel. Rounding will follow conventional rules, whereby a value of 0.50 or larger is rounded up to 1 and a value less than 0.50 is rounded down to 0. After rounding, the resulting total nominal days of all vessels could slightly exceed or fall short of the TAE.

5. Summary of the Main Results for the Four PAES Formulae

This section summarizes the gains in vessel daily operating profit due to the transferable day credit scheme for the four PAES allocation formulae. The section then examines the equity and equity-efficiency trade-off for these two alternative PAES allocation formulae, using well-established equity metrics.

In what follows, for the two historical days PAES formulae, occasionally only *Best X of Y* is presented and not *Average 3 Years*, because as will be demonstrated, *Best X of Y* provides greater economic efficiency (larger daily vessel operating profit per day) than *Average 3 Years* with only minimal differences in equity of distribution to CPCs and both are fair shares.

The key results are preceded by the words "Conclusions".

5.1. Summary Statistics for Four Alternative PAES

Table 1 reports summary statistics for each of the four alternative PAES formulae. Table 1 reports summary statistics calculated over all vessels' days. Each of the four PAES formulae allocate, on average, a PAES to each vessel that is about 0.38% of the TAE.[7] *Hybrid* displays the smallest dispersion of PAES among vessels (measured by standard deviation). *Best X of Y* allocates the smallest PAES (0.028%). *Average 3 Years* allocates the largest PAES (0.62%).

Table 1. Summary Statistics for Four Alternative PAES

Type of Allocation	Mean	Standard Deviation	Minimum	Maximum
Average 3 Years	0.0042373	0.0013243	0.0003485	0.0061636
Best X of Y	0.0038462	0.0010398	0.0002811	0.0050643

[7] *Average 3 Years* gives a different mean PAES because it is calculated using different data.

Day/m³ Capacity	0.0038462	0.0018143	0.0004013	0.0056375
Hybrid	0.0038462	0.0007397	0.0003511	0.0044918

Note: No restrictions on number of days per vessel.
Average 3 Years is calculated from different data than the other three PAES formulae

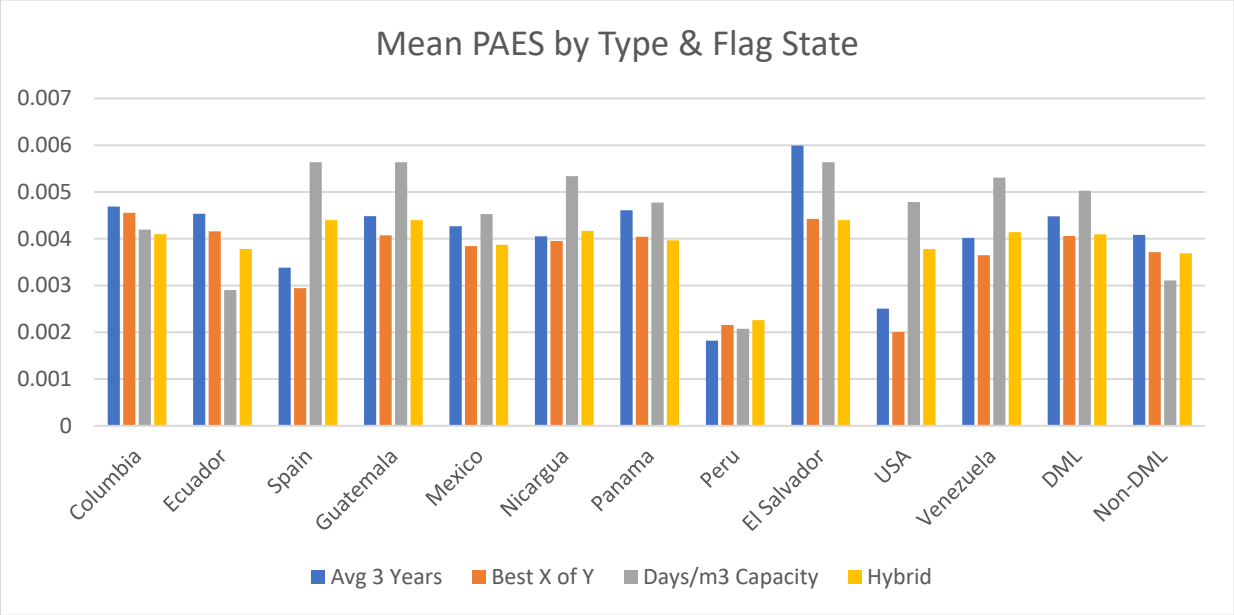
5.2. Allocation of PAES by CPC

Figure 1 depicts the mean allocated PAES for each of the four PAES allocation formulae by CPC Flag State and by vessels with and without DMLs (regardless of CPC Flag state) for all vessels regardless of the number of days.

Conclusions on Allocation of PAES by CPC:

- Some CPC Flag States display greater variation in mean PAES than others according to the type of PAES allocation formula. For example, El Salvador and the USA display considerable variation in mean PAES depending upon the formula, while Columbia and Peru display fairly stable mean PAES regardless of the formula.
- *Average 3 Days* and *Days/m³ Capacity* favor El Salvador.
- *Average 3 Days* generally gives a higher mean PAES to most CPCs than *Best X of Y*
- *Days/m³ Capacity* favors Spain, Guatemala, Mexico, Nicaragua, Panama, USA, and Venezuela plus DML holders.
- *Days/m³ Capacity* is least favorable for Ecuador.
- *Hybrid* never dominates for a CPC except very slightly for Peru.

Figure 1. Mean PAES by Type and Flag State

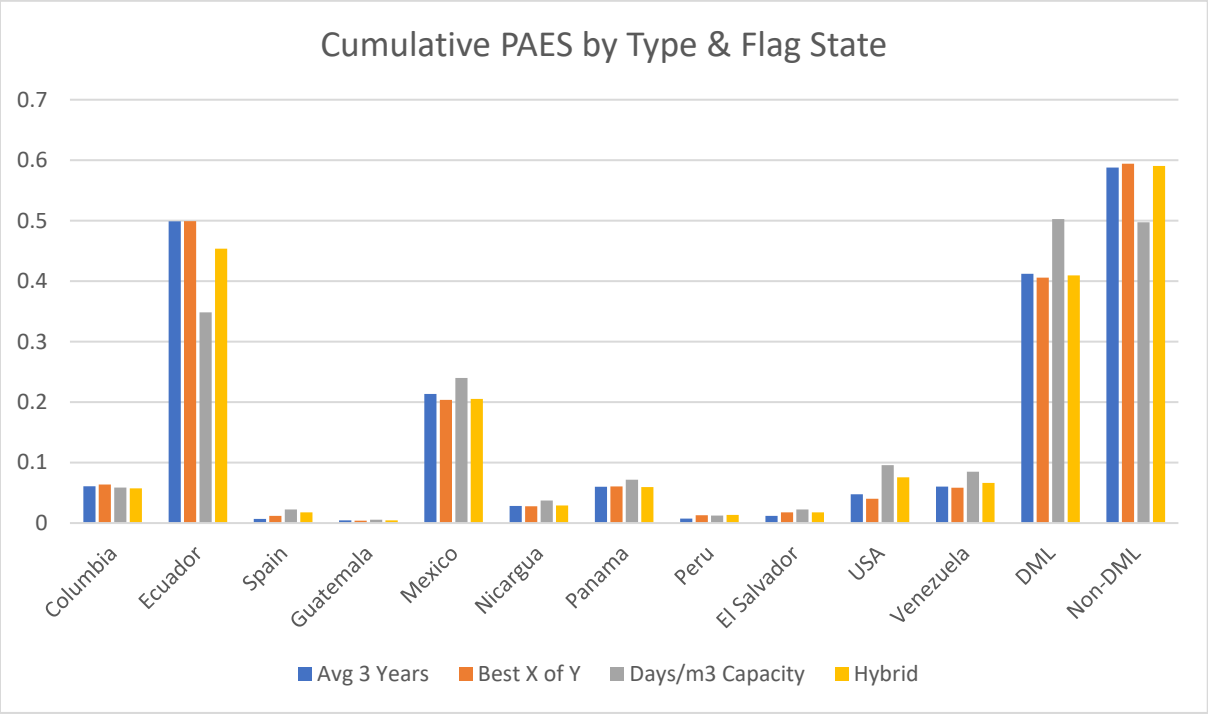


Note: No restrictions on number of days per vessel.
Average 3 Years is calculated from different data than the other three PAES formulae

Figure 2 depicts the total or cumulative PAES (summed over all vessels) for each of the four PAES allocation formulae by CPC Flag State and by vessels with and without DMLs for all vessels regardless of the number of days.
Conclusions for Allocating Total PAES by CPC:

- Ecuador followed by Mexico receive the largest total allocation of PAES by any formulae.
- Spain, Guatemala, Peru, and El Salvador receive the smallest total allocation of PAES by any formulae.
- There are more total Non-DML PAES than DML PAES.
- *Days/m³ Capacity* is the least favorable PAES formulae for Ecuador but the most favorable for Mexico, USA, and Venezuela plus DML holders.

Figure 2. Cumulative PAES by Type and CPC Flag State



Note: No restrictions on number of days per vessel.
Average 3 Years is calculated from different data than the other three PAES formulae

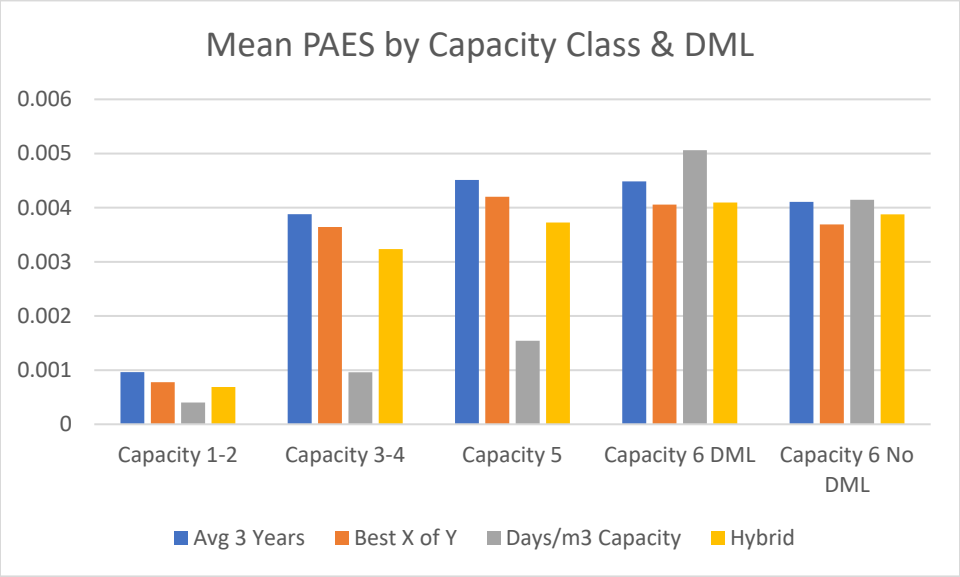
5.3. Allocation of PAES by Capacity Class and DML

Figure 3 depicts the mean allocated PAES to each capacity class, regardless of Flag State, for each of the four PAES formulae. Because all DML holding vessels are Class 6, Class 6 vessels are distinguished between DML and non-DML.

Conclusions on Allocation of PAES by Capacity Class and DML:

- Different PAES formulae favor different capacity classes in terms of mean PAES per vessel
- *Days/m³ Capacity*: smaller capacity classes receive fewer days and larger capacity classes receive more days
- *Average 3 Years:* generally gives the highest mean PAES by capacity class
- *Hybrid* gives the third highest mean PAES for all capacity classes and DML or non-DML

Figure 3. Mean PAES by Type and CPC Flag State



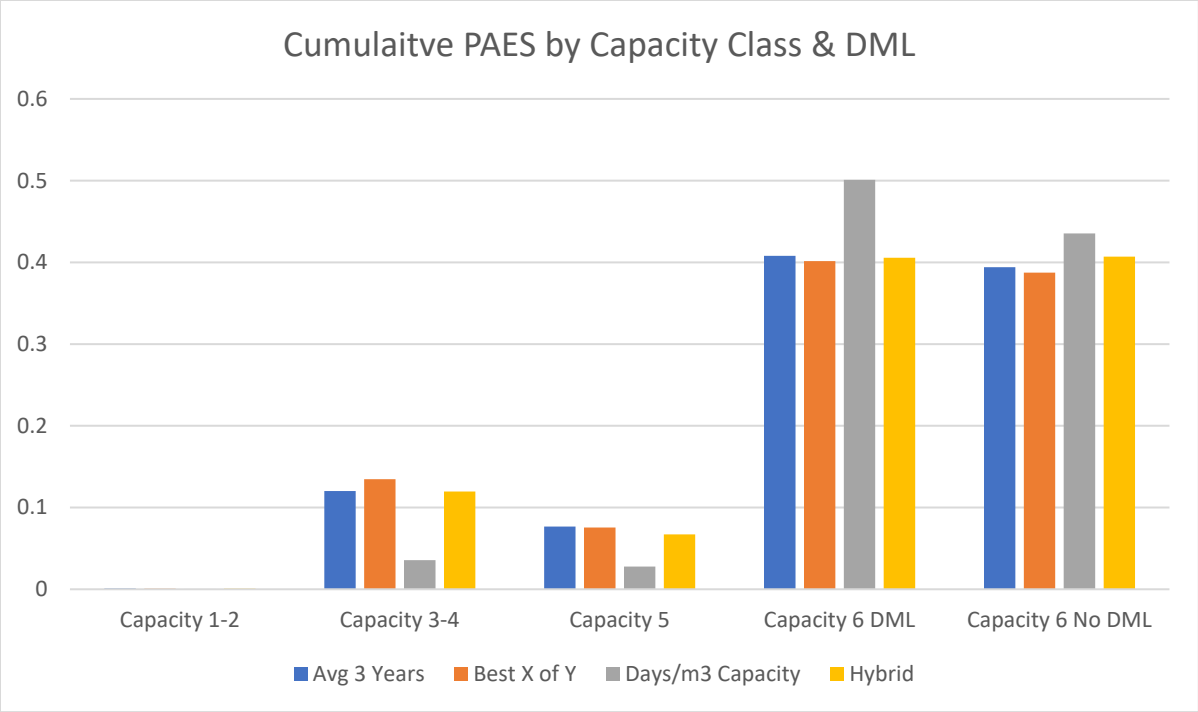
Note: No restrictions on number of days per vessel.
Average 3 Years is calculated from different data than the other three PAES formulae

Figure 4 depicts the total or cumulative PAES for each of the four PAES allocation formulae by capacity class, with Capacity Class 6 differentiated by whether or not the vessel holds a DML, for all vessels regardless of the number of days.

Conclusions on the cumulate allocation of PAES by capacity class and Flag State include:

- Capacity Class 6 vessels receive the lion's share of PAES
- *Days/m³ Capacity* PAES dominates Capacity Class 6 total PAES, and is especially dominant for Capacity Class 6 vessels with DML
- *Days/m3 Capacity gives the smallest total PAES for Capacity Classes 1-5*
- *Average 3 Years, Best X of Y*, and *Hybrid* give very similar total PAES to Capacity Class 6 vessels with and without DMLs

Figure 4. Cumulative PAES by Capacity Class and Flag State



Note: No restrictions on number of days per vessel.
Average 3 Years is calculated from different data than the other three PAES formulae

5.4. How Rapidly Are PAES Allocated?

Pen's Parade for allocation PAES by vessel in this section depicts the variation and concentration.

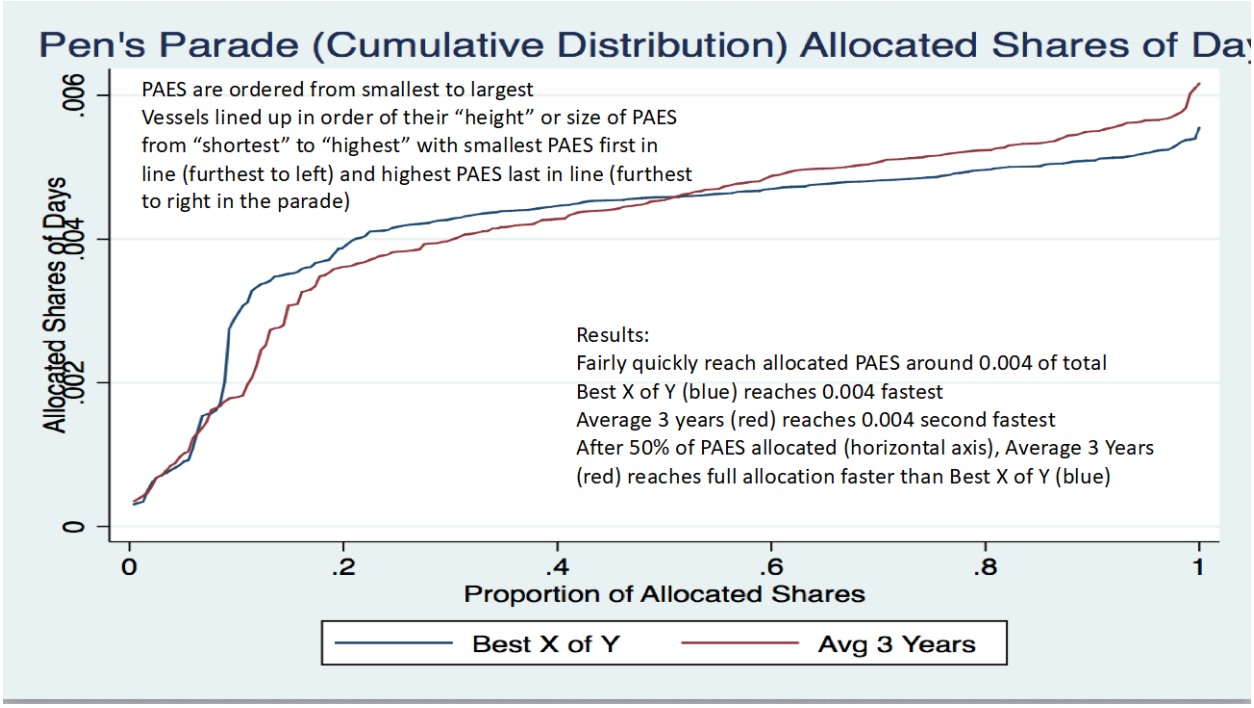
Conclusions on How Rapidly *Best X of Y* and *Average 3 Years* PAES are Allocated:

- Best X of Y more rapidly allocates smaller PAES than Average 3 Years but after about 50% of the PAES are allocated Average 3 Years more rapidly allocates PAES than Best X of Y.

The following figures illustrate "Pen's Parade" or cumulated distribution of allocated PAES for *Best X of Y* and *Average 3 Years*. PAES per vessel are ordered from the smallest to largest. The smaller PAES are on the left-hand side of the figure (closer to zero on the horizontal axis). The larger PAES are on the right-hand side of the figure (closer to one on the horizontal axis). The vertical axis shows the cumulated or summed PAES, where closer to zero on the vertical axis pertains to allocation of only the smaller PAES and the closer to the top of the vertical axis the more PAES are allocated (starting with smaller and ending with larger PAES).

Figure 5's results show that a larger proportion of the smaller PAES are more quickly allocated with the *Best X of Y* (blue line) than the *Average 3 Years* (red line). After about 50% of the PAES are allocated, the *Average 3 Years* PAES is slightly larger than the size of the *Best X of Y* PAES.

Figure 5. Pen's Parade (Cumulative Distribution) of Allocated PAES for Historical Days



Note: No restrictions on vessels' days. *Average 3 Years* and *Best X of Y* calculated on same data set. This data set and calculated *Best X of Y* differ for *Best X of Y, Days/m³ Capacity*, and *Hybrid*.

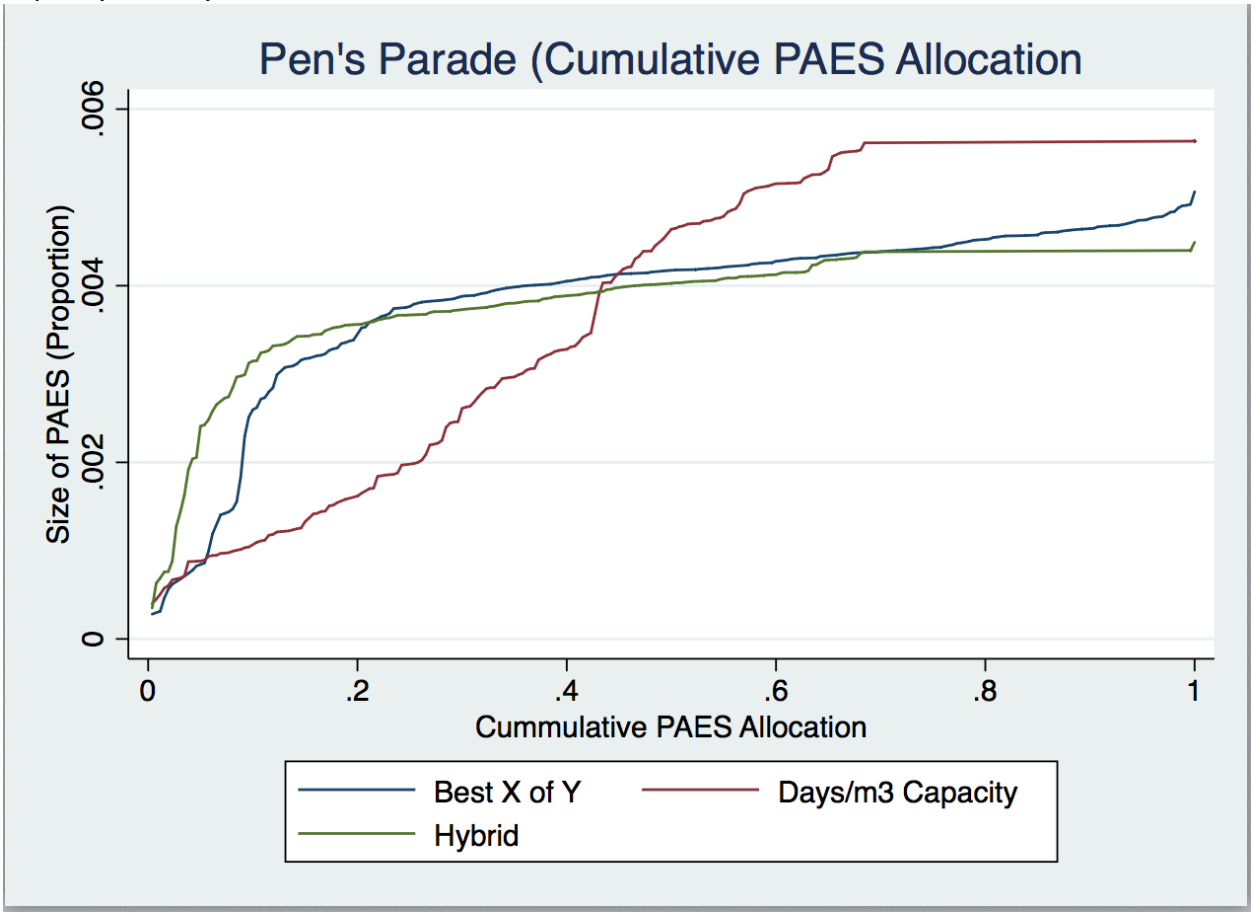
The following Pen's Parade diagram in Figure 6 illustrates how rapidly *Best X of Y*, *One Day/m³ of Capacity,* and *Hybrid* PAES are allocated.

Conclusions on How Rapidly *Best X of Y*, *One Day/m³ of Capacity,* and *Hybrid* PAES are Allocated:

- Even though *Hybrid* blends *Best X of Y* and *Days/m³ Capacity*, *Hybrid* allocates PAES very similar to *Best X of Y*
    - *Best X of Y* dominates the type of PAES allocation for most vessels and CPCs
- *Days/m³ Capacity* allocates PAES very differently than *Best X of Y* or *Hybrid*
- A larger proportion of the smaller PAES are more quickly allocated with *Hybrid*, followed by *Best X of Y* until about 20% of the shares have been allocated, and then reversing with slightly faster *Best X of Y* allocation.
- Both *Best of Y* and Hybrid reach a fairly constant PAES of about 0.04 by 40% of all PAES have been allocated, and then the size of the allocated PAES rising more slowly thereafter, with *Best X of Y* reaching larger PAES.

- *One Day/m³ of Capacity* shows more inequality in PAES size, with fewer smaller PAES and larger frequency of larger PAES, more slowly reaching equality with *Best X of Y* and *Hybrid* at about 45% of all PAES allocated and rapidly diverging with its larger PAES thereafter.

Figure 6. Pen's Parade (Cumulative Distribution) of Allocated PAES for *Best X of Y, Days/m³ Capacity,* and *Hybrid*



Note: No restrictions on vessels' days. All calculations from same data (Best X of Y).

Conclusions from the two Pen's Parade diagrams are as follows:

- Both PAES based upon historical days, *Best X of Y* and *Average 3 Years*, allocate comparably sized PAES at about the same rate.
- Both *Best X of Y* and *Hybrid* also allocate comparably sized PAES at about the same rate.
- *Days/m³ of Capacity* allocates PAES very differently than *Best X of Y*, *Average 3 Years*, or *Hybrid*
- *Days/m³ of Capacity* has fewer smaller PAES and a greater proportion of larger PAES that are also substantially larger than *Best X of Y* and *Hybrid*.

5.5. Frequency Distribution of Allocated PAES by Vessel

Frequency distributions of allocation PAES by vessel in this section depict the variation and concentration.

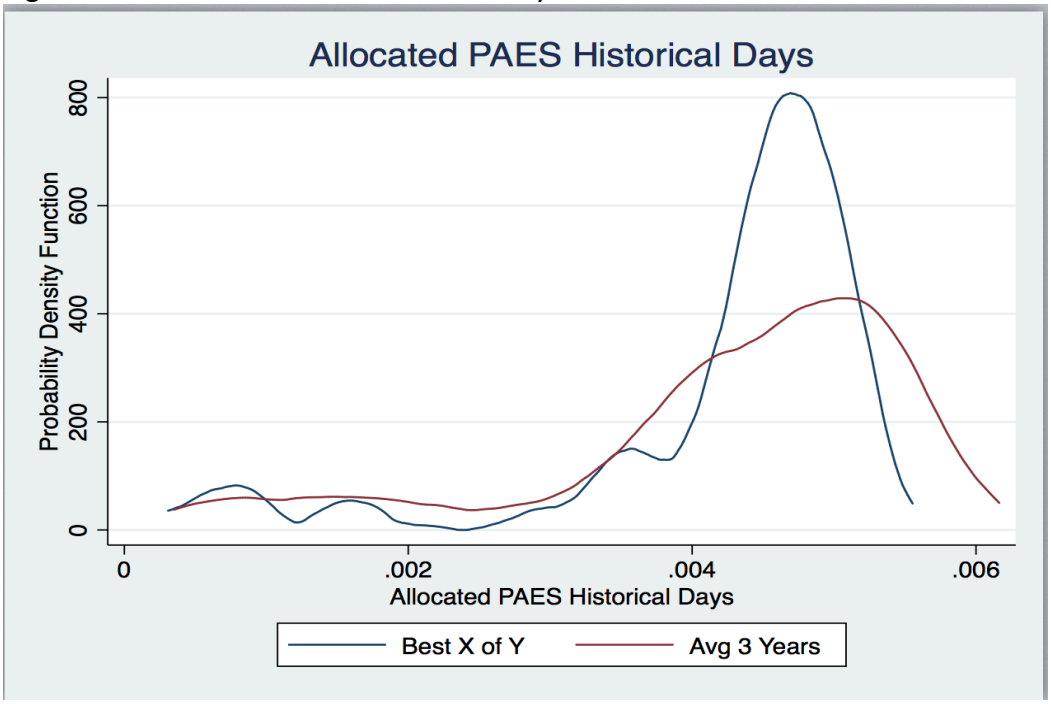
Conclusions on the Frequency Distribution of Allocated PAES by Vessel:

- All methods of allocating PAES give a wide range between smallest and largest allocated PAES
- *Best X of Y* and *Hybrid* are very similar compared to *Days/m³ Capacity*

Figure 7 depicts the frequency distribution for allocated PAES for the two historical days formulae, *Average 3 Days* and *Best X of Y*. Figure 7 shows that:

- Both *Average 3 Days* and *Best X of Y* are widely distributed, ranging from very small to large PAES
- *Average 3 Days* has larger PAES than *Best X of Y*
- *Best X of Y* is more concentrated around a single value (slightly larger than the mean PAES) than *Average 3 Days*

Figure 7. Allocated PAES for Historical Days



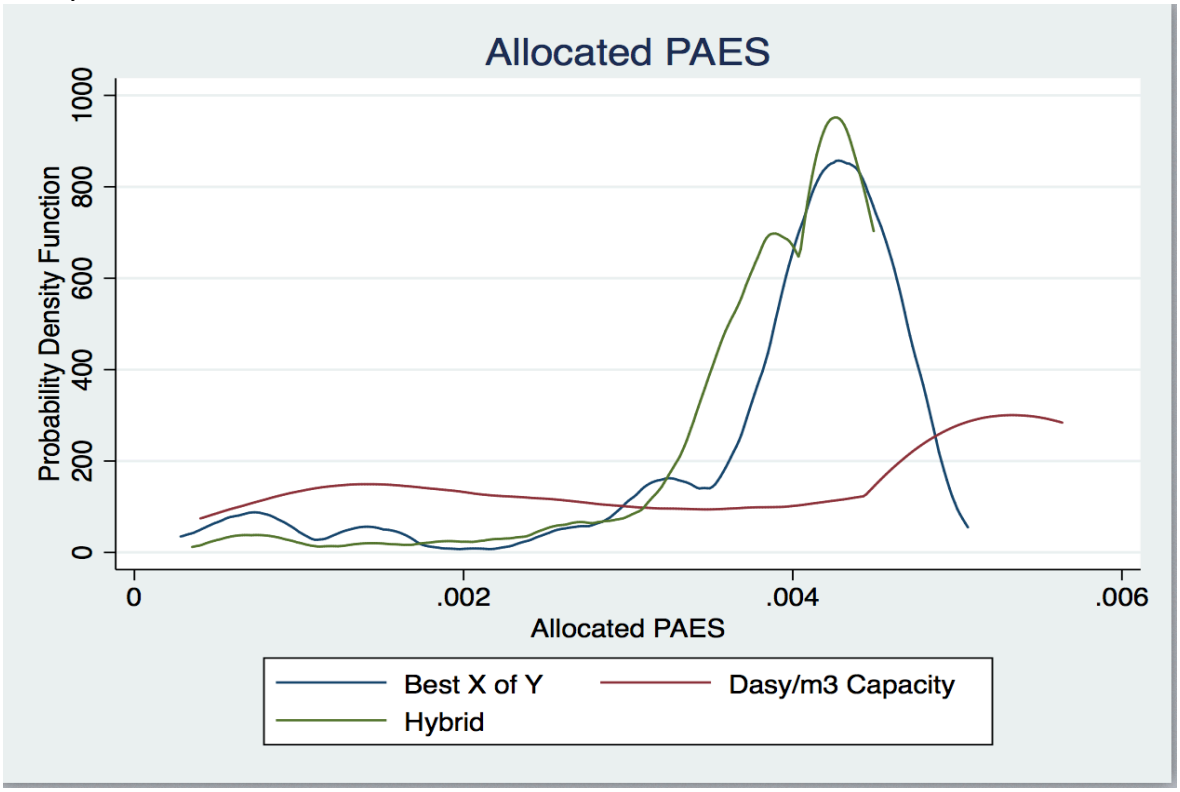
Note: No restrictions on vessels' days.

The frequency distribution of allocated PAES per vessel for *Best X of Y, Days/m³ Capacity*, and *Hybrid* are depicted in Figure 8.

Conclusions on the frequency distribution of allocated PAES for *Best X of Y, Days/m³ Capacity*, and *Hybrid*:

- *Best X of Y* and *Hybrid* have relatively similar frequency distributions for allocated PAES when compared to the visibly different *Days/m³ Capacity*
- *Days/m³ Capacity* is more widely distributed than *Best X of Y* and *Hybrid*.
    - *Days/m³ Capacity* has the smallest minimum values and largest maximum PAES per vessel and does not have the concentrated or "bunched" PAES centered around the mean PAES of about 0.004.
- *Best X of Y* has more PAES per vessel that are larger than *Hybrid,* and is centered around a slightly larger value than *Hybrid*.

Figure 8. Frequency Distribution of Allocated PAES for *Best X of Y, Days/m³ Capacity*, and *Hybrid*



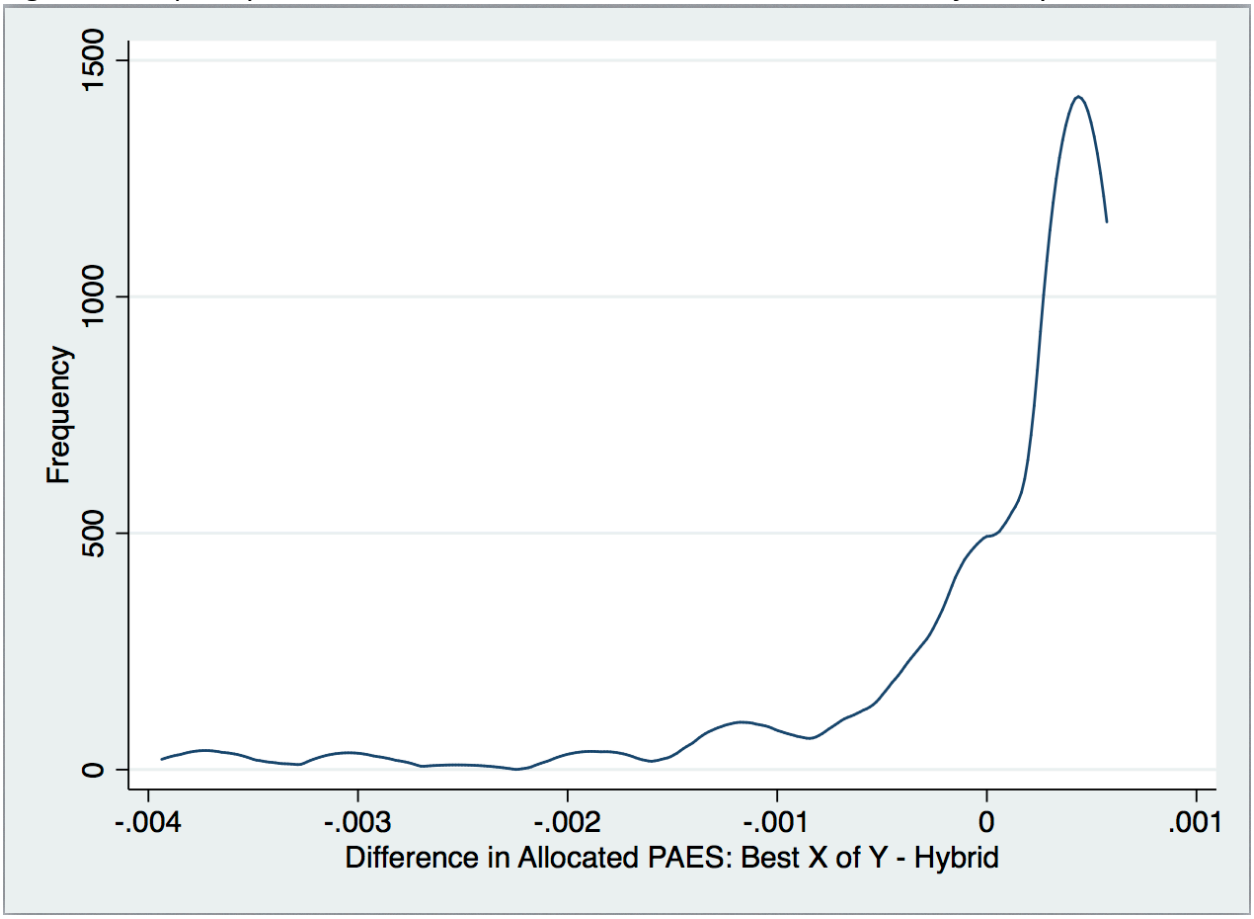
Note: No restrictions on vessels' days. All calculations from same data (Best X of Y).

Figure 9 depicts the frequency distribution for the difference in allocated PAES between *Best X of Y* and *Hybrid*, calculated as the PAES for *Best X of Y* minus the PAES for *Hybrid*.

Conclusion on the frequency distribution of differences in allocated PAES between *Best X of Y* and *Hybrid*:

- For most PAES, PAES *Best X of Y* > *Hybrid,* the same conclusion drawn from Figure 9

Figure 9. Frequency Distribution of Difference in Allocated PAES: *Best X of Y - Hybrid*



5.6. Equity in PAES Allocation

This section evaluates the equity of the allocated PAES using standard equity metrics from economics and information theory.

Conclusions on the Equity in PAES Allocation:

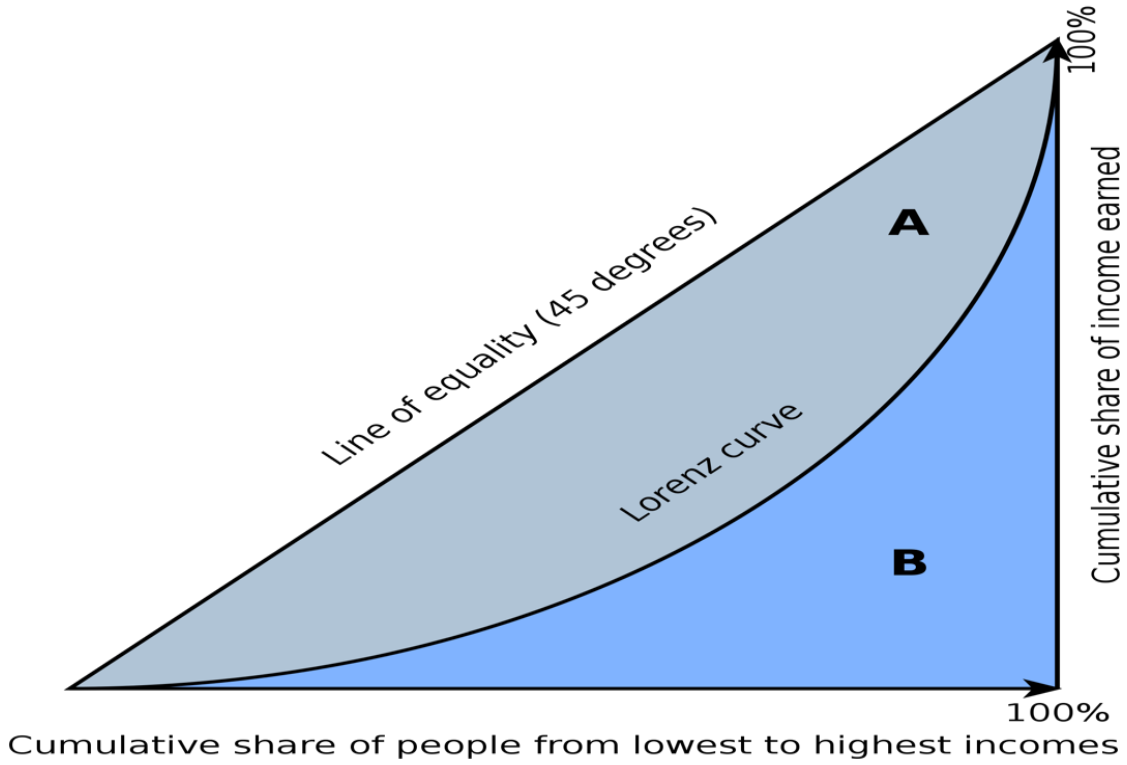
- All four alternative ways to allocate PAES give a high degree of equity according to standard equity metrics.
- The ranking in equity from highest equity to lowest equity is: *Hybrid* > *Best X of Y* > *Average 3 Years* > *Days/m^3 Capacity*

5.6.1. Lorenz Curve for Equity in Allocating PAES by Individual Vessel

The Lorenz Curve here is a graphical representation of the distribution of PAES within a population of vessels. The Lorenz Curve plots cumulated percentiles of the vessels on the

horizontal axis according to PAES and plots cumulative PAES on the vertical axis. The 45-degree line represents perfect equality and the further from the 45-degree line the greater the inequality. The ratio of the area A to A+B, i.e. $\frac{A}{A+B}$, gives the Gini Coefficient (which is used in the next sub-section).

Figure 10. The Lorenz Curve



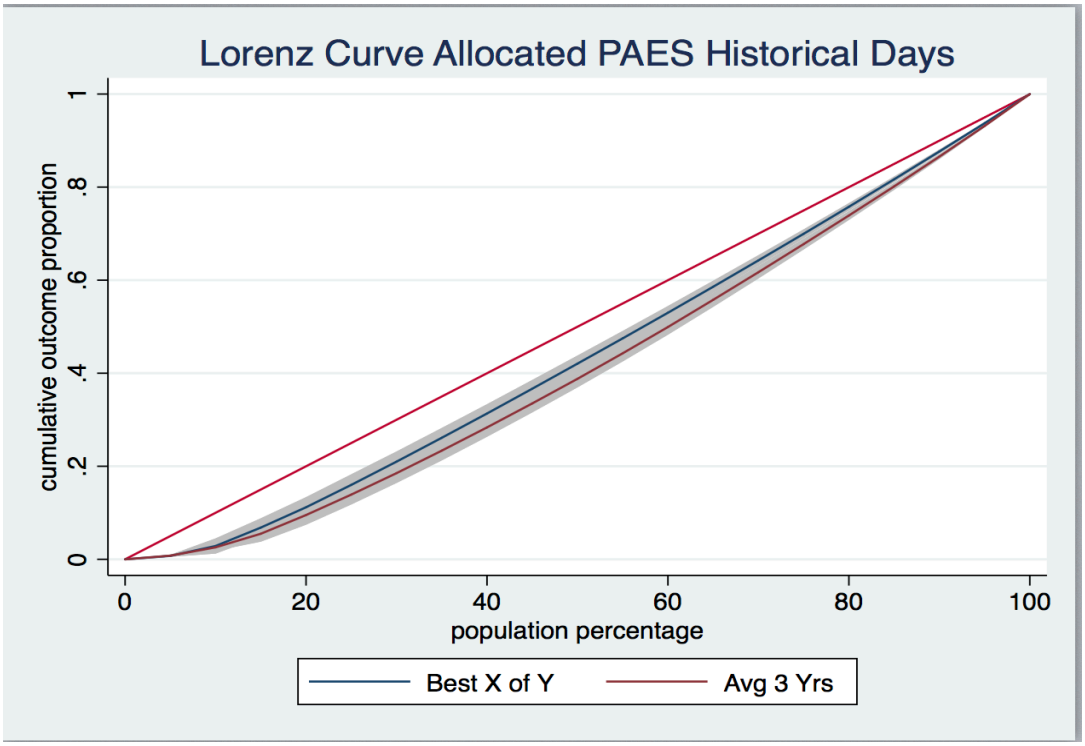
Conclusions on Equity from the Lorenz Curve:

- *Average 3 Days*, *Best X of Y*, and *Hybrid PAES* are all very similarly equitably allocated and with a high degree of equity (closeness to diagonal line)
- *Days/m³ Capacity* is visibly the least equitably allocated among vessels.

The Lorenz Curve in Figure 11 for shows that:

- Allocated PAES for *Best X of Y* is has slightly more equity (closer to the diagonal line) than *Average 3 Years* inn allocation among vessels
- Both PAES predicated upon historical days have basically the same equity in allocation among vessels.

Figure 11. Lorenz Curve for Allocated PAES Historical Days

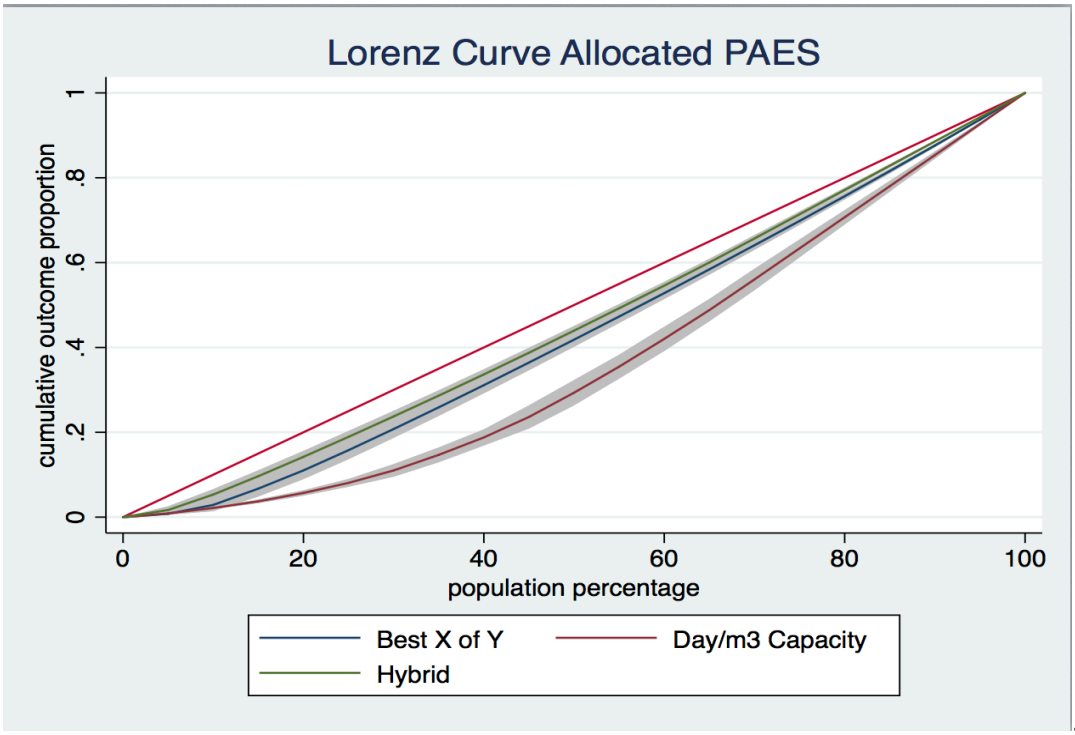


Note: No restrictions on vessels' days. All calculations from same data
Diagonal line is perfect equity. Closer to (farther from) diagonal line indicates greater (lesser equity).

The Lorenz Curve in Figure 12 for allocated PAES show that:

- Both *Best X of Y* and *Hybrid* are allocated among vessels with high equity (closeness to diagonal line),
- *Hybrid* is slightly more equitably allocated among vessels than *Best X of Y*
- *Days/m^3 Capacity* is visibly less equitably allocated among vessels.

Figure 12. Lorenz Curve for Allocated PAES *Best X of Y, Days/m^3 Capacity*, and *Hybrid*



Note: No restrictions on vessels' days. All calculations from same data
Diagonal line is perfect equity. Closer to (farther from) diagonal line indicates greater (lesser equity).

The overall conclusion for equity in PAES allocation among vessels is that:

- *Average 3 Days*, *Best X of Y*, and *Hybrid PAES* are all very similarly equitably allocated and with a high degree of equity (closeness to diagonal line)
- *Days/m³ Capacity* is visibly the least equitably allocated among vessels.

5.6.2. Equity Metrics for Allocated PAES

Conclusions on the equity of allocated PAES by vessels:

- All four alternative ways to allocate PAES give a high degree of equity according to standard equity metrics.
- The ranking in equity from highest equity to lowest equity is: *Hybrid* > *Best X of Y* > *Average 3 Years* > *Days/m³ Capacity*

Table 2. Equity Metrics for Different PAES

Type of PAES Allocation	Gini Coefficient	Ratio of 90th Percentile to 10th Percentile	Theil's Generalized Entropy GE(1)	Atkinson's Inequality Measure (γ=1)
Average 3 Years	0.16258	1.209	0.06225	0.08958
Best X of Y	0.12636	1.782	0.04937	0.07679
Days/m³ Capacity	0.26022	5.151	0.13042	0.15962
Hybrid	0.08827	1.397	0.02379	0.03476

No restrictions on number of days per vessel.
Average 3 Years is calculated from different data than the other three PAES formulae
Atkinson: Lower values more equal, $0 \leq A(\gamma = 1) \leq 1$. Atkinson can be interpreted as the percentage of per capita "income" (here daily vessel operating profit per vessel) that would provide the same total welfare as the actual "income" if it were equally distributed.
Gini Coefficient: Lower values more equal, $0 \leq G \leq 1$.
Theil's Generalized Entropy: Lower values more equal, $0 \leq GE(1) \leq \infty$.

6. Maximum Potential Short-Run Efficiency Gains: Daily Vessel Operating Profit

This section evaluates the efficiency gains and equity impacts in terms of daily vessel operating profit for the alternative PAES allocation schemes.

This analysis is short-run because it does not include consolidation of days among multi-vessel companies and accompanying savings in fixed costs. This consolidation of days likely leads to a large increase in profitability, but cannot be estimated since all data are without identifiers of vessel or company. The analysis provides the maximum potential gains because the analysis assumes perfect transferability of credits without costs of information, transactions, CPC Flag State transfers, plus constant prices and constant catch per unit of effort.

A separate analysis of the Ecuador ex-vessel tuna market shows that there can be slight revenue gains by shifting harvests to the first quarter of the year, but the results are very small; the impact of shifting landings to different times of the year is very small.

The analysis excludes vessels with fewer than 99 days for vessels without a DML because such vessels are visibly different and including them led to nonsensical quantitative results. These vessels included the single trips for US vessels allowed from the Western and Central Pacific and some Peruvian and Ecuadorian vessels. These vessels were assumed to be qualitatively different (e.g. different behavioral objectives or having been subject to mechanical issues, etc.) from the other vessels and were thus excluded from the analysis. Of the 18 excluded non-DML vessels in the *Best X of Y* allocation, 10 were US vessels. Two DML vessels had fewer than 99 days, but were included in the analysis since their inclusion did not visibly impact the analysis.

6.1. Economic Efficiency: Daily Vessel Operating Profit

Conclusions*: The maximum economic efficiency results when comparing before and after the scheme for daily vessel operating profit are:*

- *Best X of Y > Average 3 Years > Hybrid > Days/m^3 Capacity*
- *Some vessels displayed negative vessel daily vessel operating profit before the transferable day credit scheme.*

- *Some, but fewer, vessels still displayed negative albeit lower daily vessel operating profit after the scheme.*
- *Some highest-performing vessels' daily vessel operating profit remains unchanged even after the transferable day credit scheme, since these vessels are already optimally performing.*
- *The reported changes in daily vessel operating profit following the transferable day credit scheme are due to improved vessel operations from more flexible fishing (with constant prices).*
- The results exclude gains in profit from reorganization within multi-vessel companies.
    - *Further research for simulated multi-vessel companies, whereby companies can choose the optimum combination of days for each vessel, indicates that multi-vessel companies can expect considerably larger gains in daily vessel operating profit.*

6.1.1. Mean Vessel Daily Operating Profit

The following table summarizes the daily vessel operating profit for the four alternative PAES. Prior to the transferable day scheme, the mean daily vessel operating profit (applicable to all PAES for *Best X of Y, Days/m^3 Capacity*, and *Hybrid)* is $5,843 with some vessels making losses (negative values) and others with a high value of $55,512. Those vessels with the high value of $55,512 are the highest performing vessels. Because they are the highest performers, the daily vessel operating profit remains unchanged even after introducing the transferable day scheme.

Table 3. Summary Statistics Daily Vessel Operating Profit ($)

Type of PAES Allocation	Mean	Standard Deviation
Before:		
Average 3 Years	5,036	10,008
Best X of Y	5,843	8,931
Days/m^3 Capacity	5,843	8,931
Hybrid	5,843	8,931
After:		
Average 3 Years	7,097	11,365
Best X of Y	8,367	11,488
Days/m^3 Capacity	6,733	9,750
Hybrid	7,263	9,897

Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results.
Average 3 Years calculated from different data than the other PAES allocation formulae.
Differences calculated directly from individual vessel observations.
Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The PAES allocations ranked from the highest to lowest mean daily vessel operating profit after the transferal day credit scheme are:

1. *Best X of Y*: $8,367
2. *Hybrid*: $7,263
3. *Average 3 Years*: $7,097
4. *Days/m^3 Capacity*: $6,733

The most likely explanation is that historical days best reflects existing optimal use, which can be expected to carry forward into the pilot Transferable Day Credit Scheme. *Best X of Y* (and thus *Hybrid*) have higher daily vessel operating profit than *Average 3 Years* because *Best X of Y* inherently chooses the best years for a vessel.

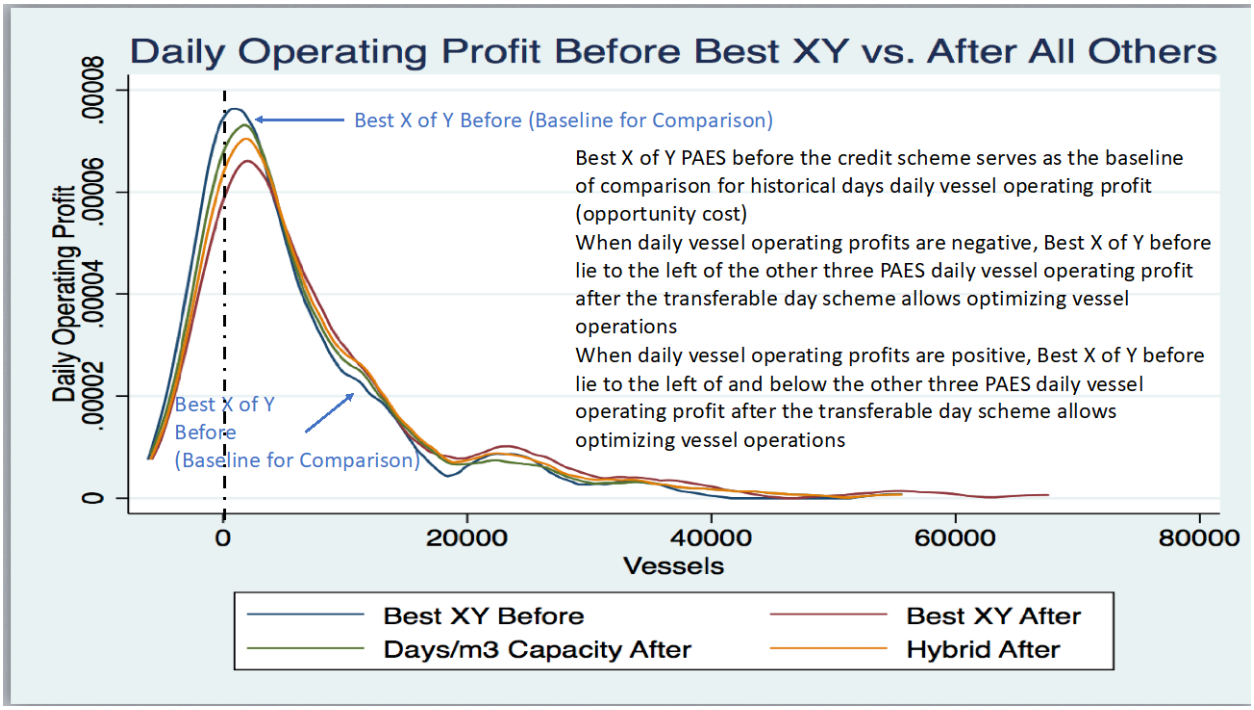
Paired t-Tests for statistically significant differences in mean daily vessel operating profit lead to the following Conclusions:

- The Scheme always leads to a statistically significant increase in daily vessel operating profit for each of the four PAES allocation alternatives compared to before the Scheme.
- Statistically significant rankings of daily vessel operating profit increase due to Scheme from largest increase to smallest increase: Best X of Y > Average 3 Years > Hybrid > Days/m^3 Capacity

6.1.2. Differences between Before and After Vessel Daily Operating Profit

The graphical results in the following figure depict that all the **after** daily vessel operating profits for *Best X of Y, Day/m3 Capacity*, and *Hybrid* exceed the *Best X of Y* opportunity cost of daily vessel operating profit **before** the Scheme, confirming the mean values and paired t-tests presented above.

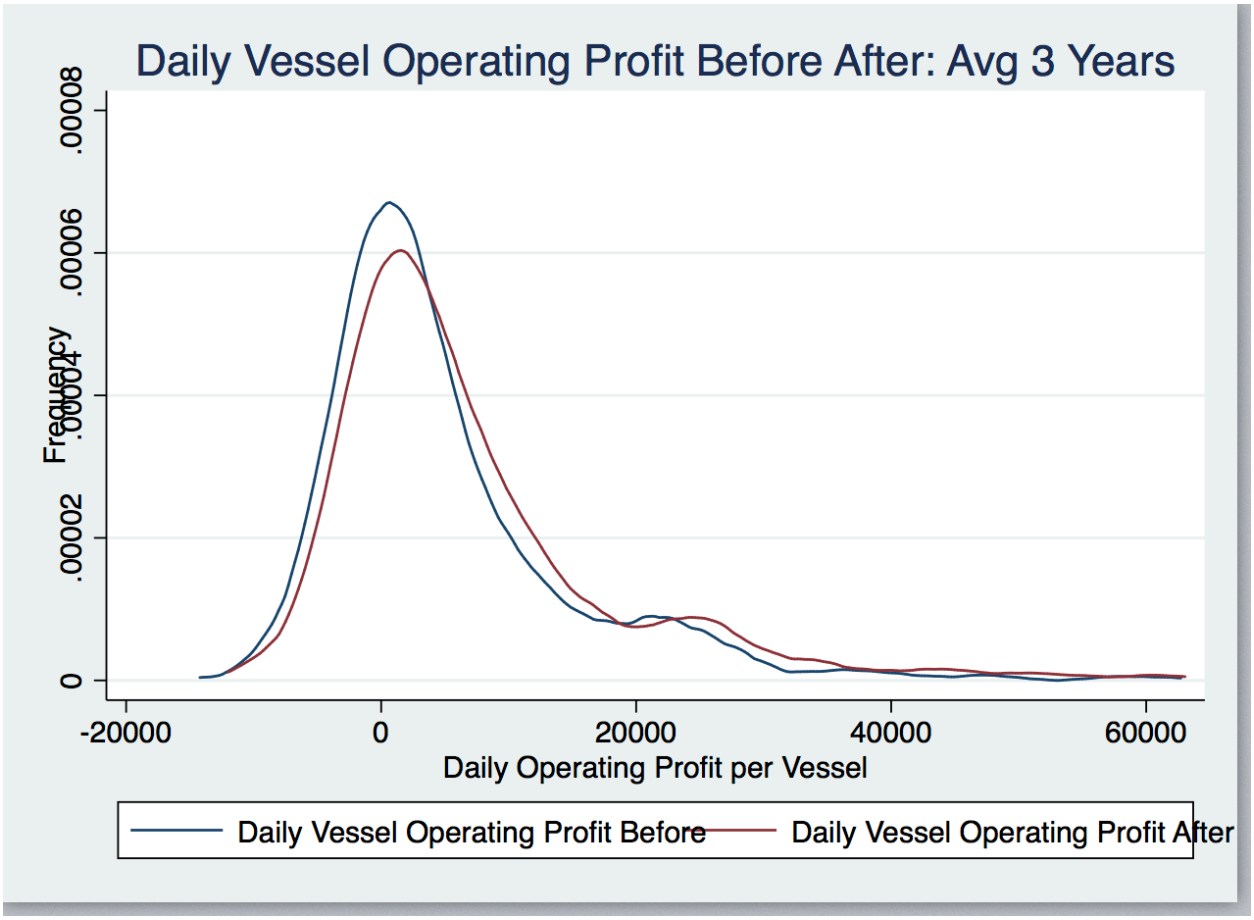
Figure 13. Daily Vessel Operating Profit **After** for *Best X of Y, Day/m3 Capacity*, and *Hybrid* compared to *Best X of Y* **Before** the Scheme



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 14A depicts daily vessel operating profit before and after the Scheme for the PAES allocation formulae *Average 3 Years*. The "after" line on the left-hand side of 0 lies inside of the "before" line and lies outside of the "before" line on the right-hand side of 0. The somewhat smaller peak and its slight rightward shift indicate an increase in daily vessel operating profit (vessels were shifted rightward into the right-hand tail). These results indicate that the "after" Scheme daily vessel operating profit exceeds the "before" Scheme daily vessel operating profit.

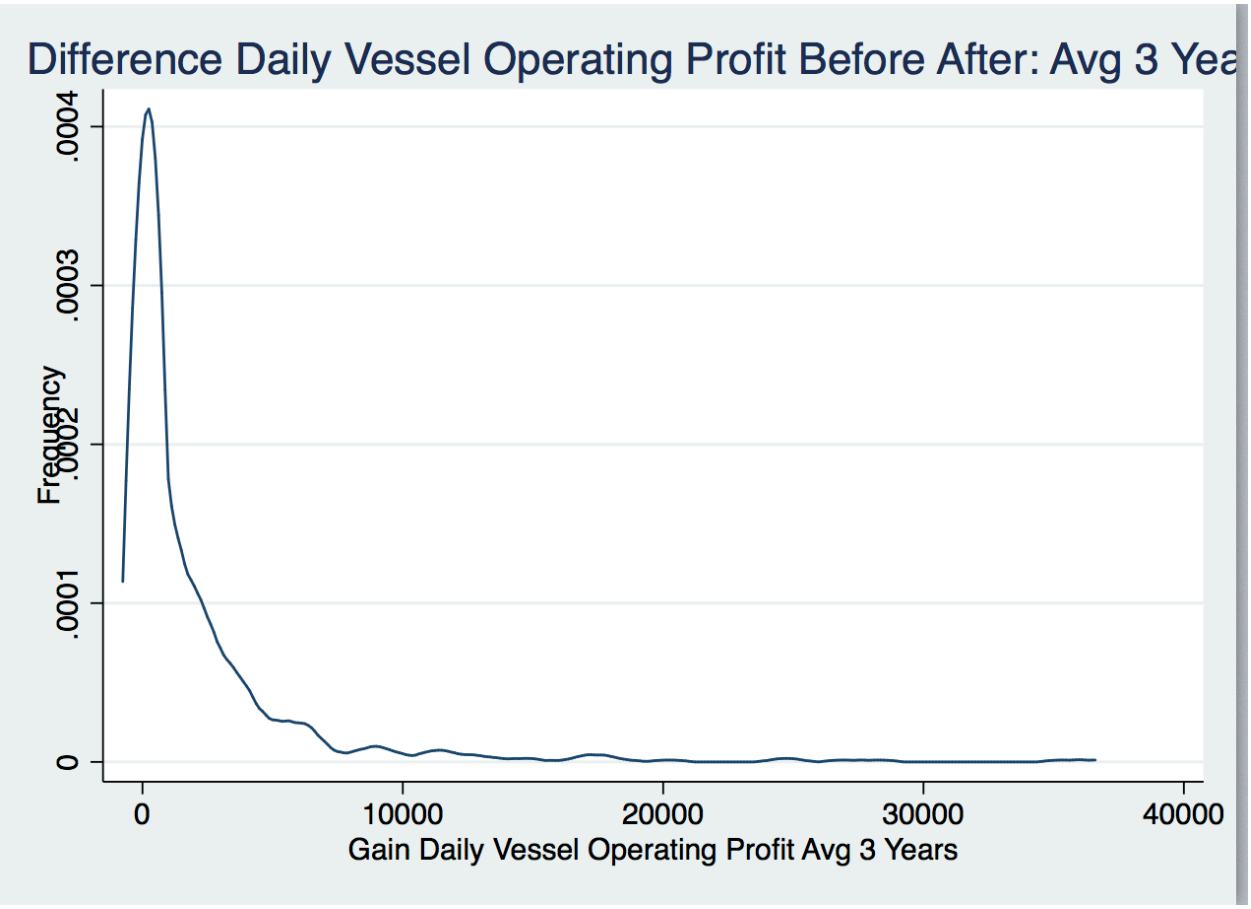
Figure 14A. Daily Vessel Operating Profit Before and After: *Average 3 Years*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 14B illustrates the difference in vessel daily operating profit before and after the *Average 3 Years* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). (This difference is calculated by daily vessel operating profit after the scheme minus before the scheme.) Figure 14B shows that daily vessel operating profit increases due to the Scheme as indicated by the long right-hand tail. Most vessels are bunched together but some vessels enjoy exceptionally large increases in daily vessel operating profit.

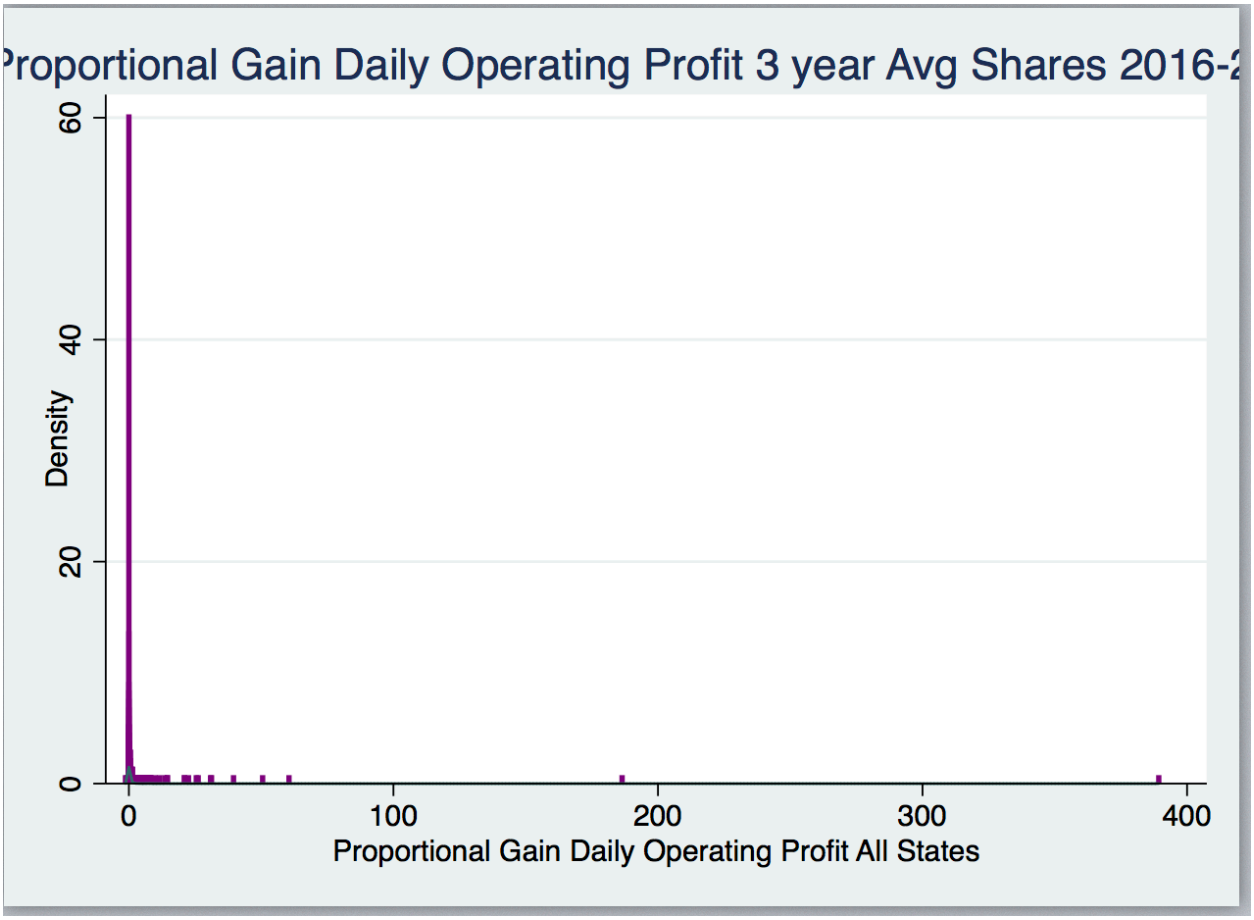
Figure 14B. Difference in Vessel Daily Operating Profit Before and After: *Average 3 Years*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 14C depicts the proportional gain in daily vessel operating profit for *Average 3 Years* due to the *Average 3 Years* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). These results show that daily vessel operating profit increases, some with proportionately large increase, as indicated by the long right-hand tail. Most vessels are bunched together with moderate increases in daily vessel operating profit. No vessel is made worse off due to the Scheme.

Figure 14C. Proportional Gain in Daily Operating Profit: *Average 3 Years*



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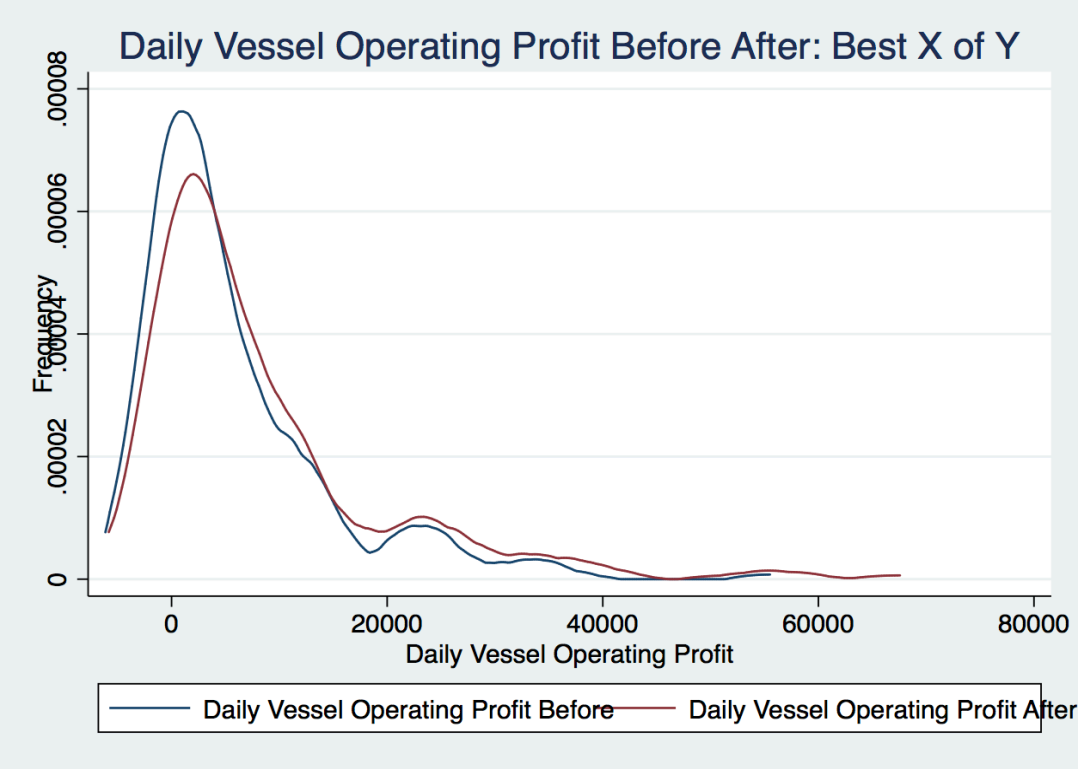
The following Figure 15A depicts daily vessel operating profit before and after the Scheme for the PAES allocation formulae *Best X of Y*. The "after" line on the left-hand side of 0 lies inside of the "before" line and lies outside of the "before" line on the right-hand side of 0. The somewhat smaller peak and its slight rightward shift indicate an increase in daily vessel operating profit (vessels were shifted rightward into the right-hand tail). These results indicate that the "after" Scheme daily vessel operating profit exceeds the "before" Scheme daily vessel operating profit.

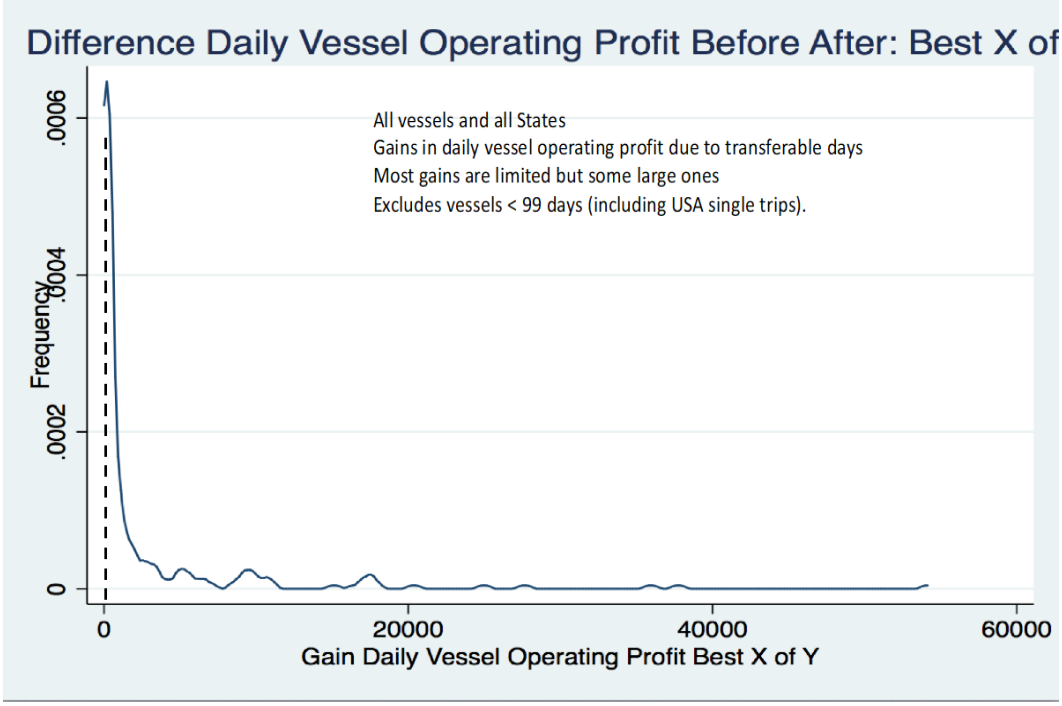
Figure 15A. Daily Vessel Operating Profit Before and After: *Best X of Y*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 15B illustrates the difference in vessel daily operating profit before and after the *Best X of Y* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). (This difference is calculated by daily vessel operating profit after the scheme minus before the scheme.) Figure 14B shows that daily vessel operating profit increases due to the Scheme as indicated by the long right-hand tail. Most vessels are bunched together but some vessels enjoy exceptionally large increases in daily vessel operating profit. No vessel is made worse off due to the Scheme.

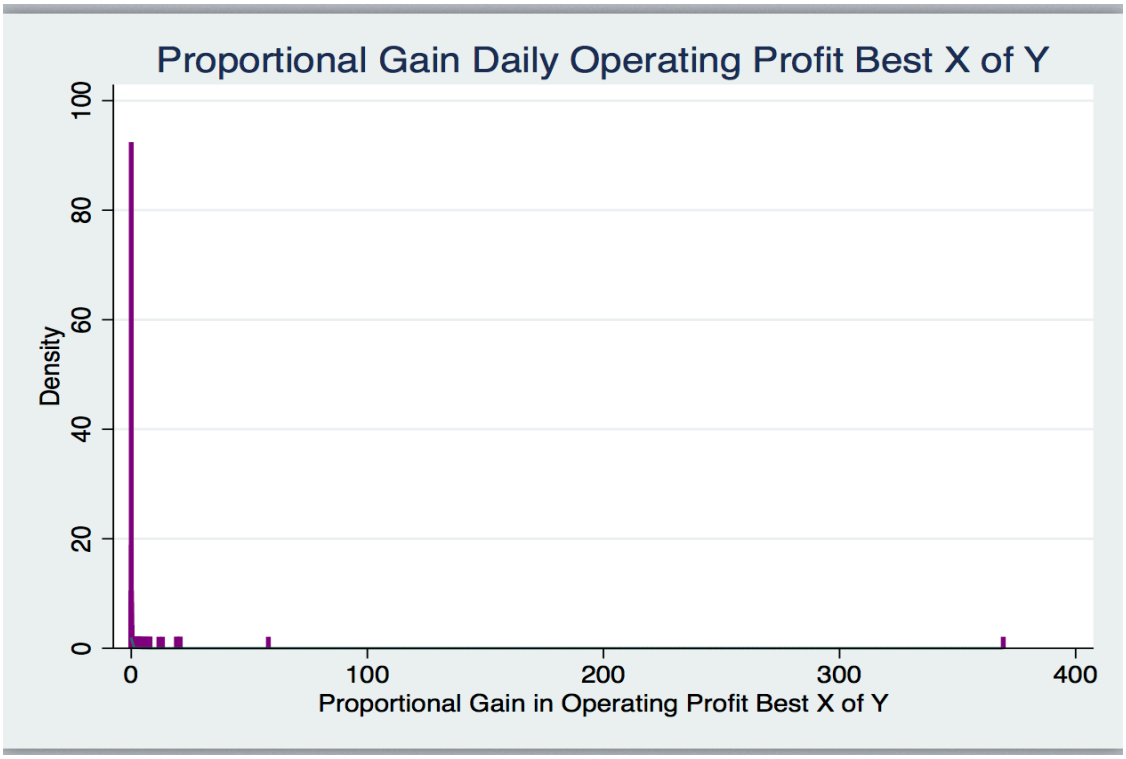
Figure 15B. Difference in Vessel Daily Operating Profit Before and After: *Best X of Y*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 15C depicts the proportional gain in daily vessel operating profit for *Best X of Y* due to the *Best X of Y* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). These results show that daily vessel operating profit increases, some with proportionately large increase, as indicated by the long right-hand tail. Most vessels are bunched together with moderate increases in daily vessel operating profit. No vessel is made worse off due to the Scheme.

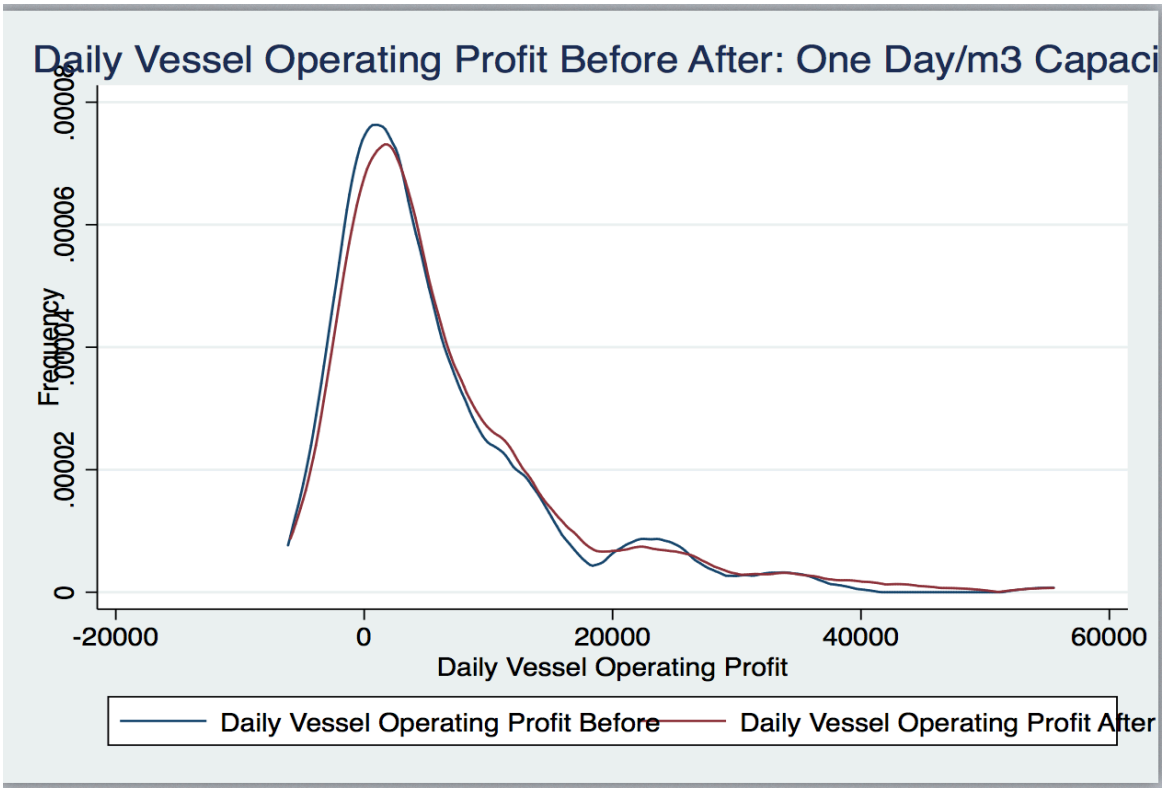
Figure 15C. Proportional Gain in Daily Vessel Operating Profit: *Best X of Y*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 16A depicts daily vessel operating profit before and after the Scheme for the PAES allocation formulae *Days/m^3 Capacity*. The "after" line on the left-hand side of 0 lies inside of the "before" line and lies outside of the "before" line on the right-hand side of 0. The somewhat smaller peak and its slight rightward shift indicate an increase in daily vessel operating profit (vessels were shifted rightward into the right-hand tail). These results indicate that the "after" Scheme daily vessel operating profit exceeds the "before" Scheme daily vessel operating profit.

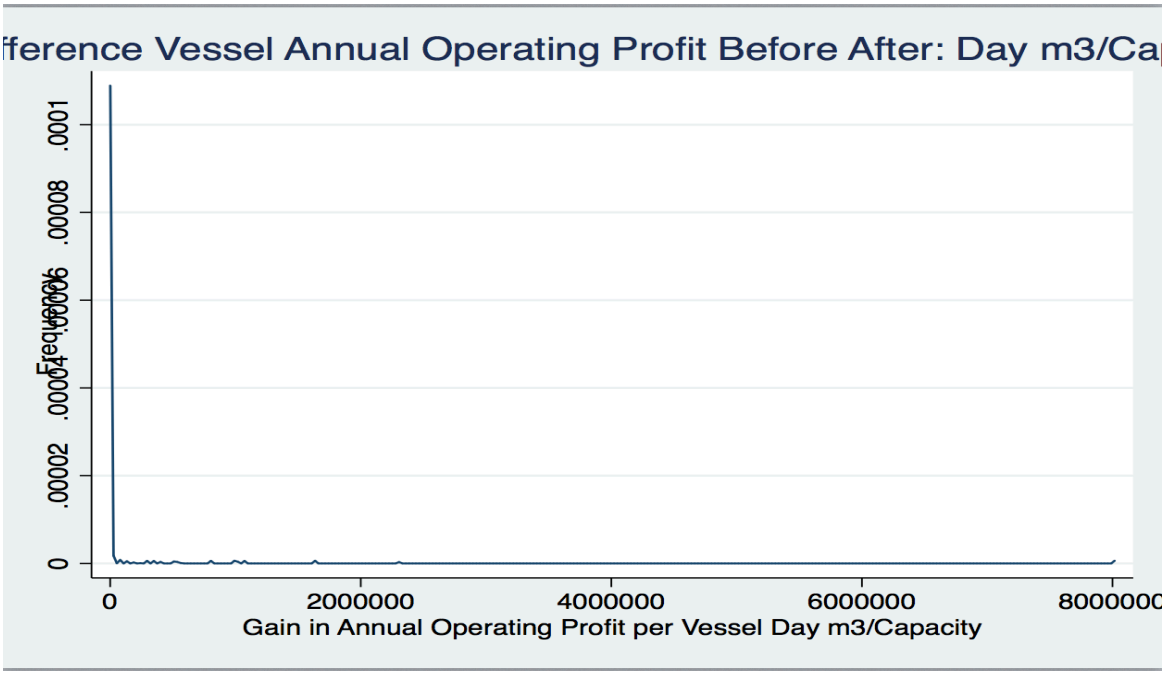
Figure 16A. Vessel Daily Operating Profit Before and After: *Days/m^3 Capacity*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 16B illustrates the difference in vessel daily operating profit before and after the *Days/m³ Capacity* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). (This difference is calculated by daily vessel operating profit after the scheme minus before the scheme.) Figure 14B shows that daily vessel operating profit increases due to the Scheme as indicated by the long right-hand tail. Most vessels are bunched together but some vessels enjoy exceptionally large increases in daily vessel operating profit. No vessel is made worse off due to the Scheme.

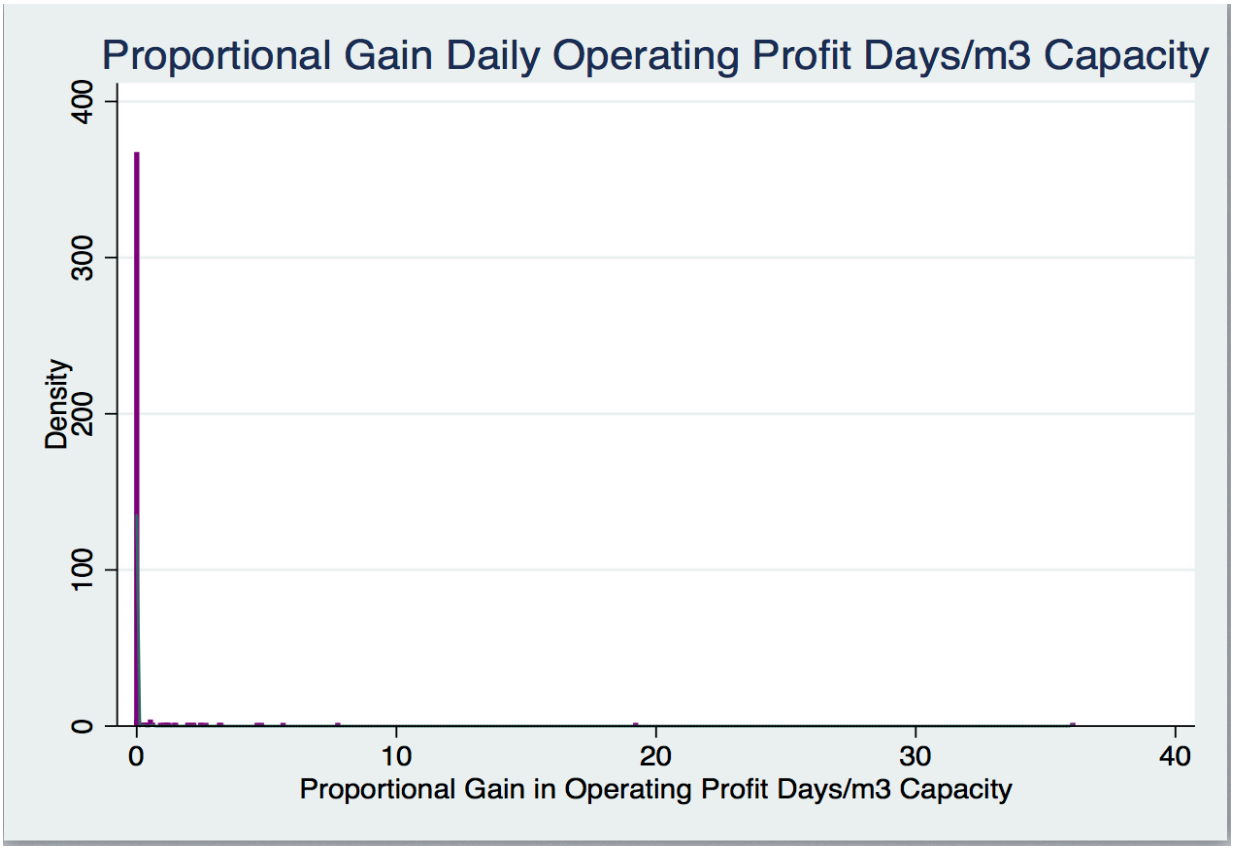
Figure 16B. Difference in Daily Vessel Operating Profit Before and After: *Days/m3 Capacity*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 16C depicts the proportional gain in daily vessel operating profit for *Days/m³ Capacity* due to the *Days/m³ Capacity* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). These results show that daily vessel operating profit increases, some with proportionately large increase, as indicated by the long right-hand tail. Most vessels are bunched together with moderate increases in daily vessel operating profit. No vessel is made worse off due to the Scheme.

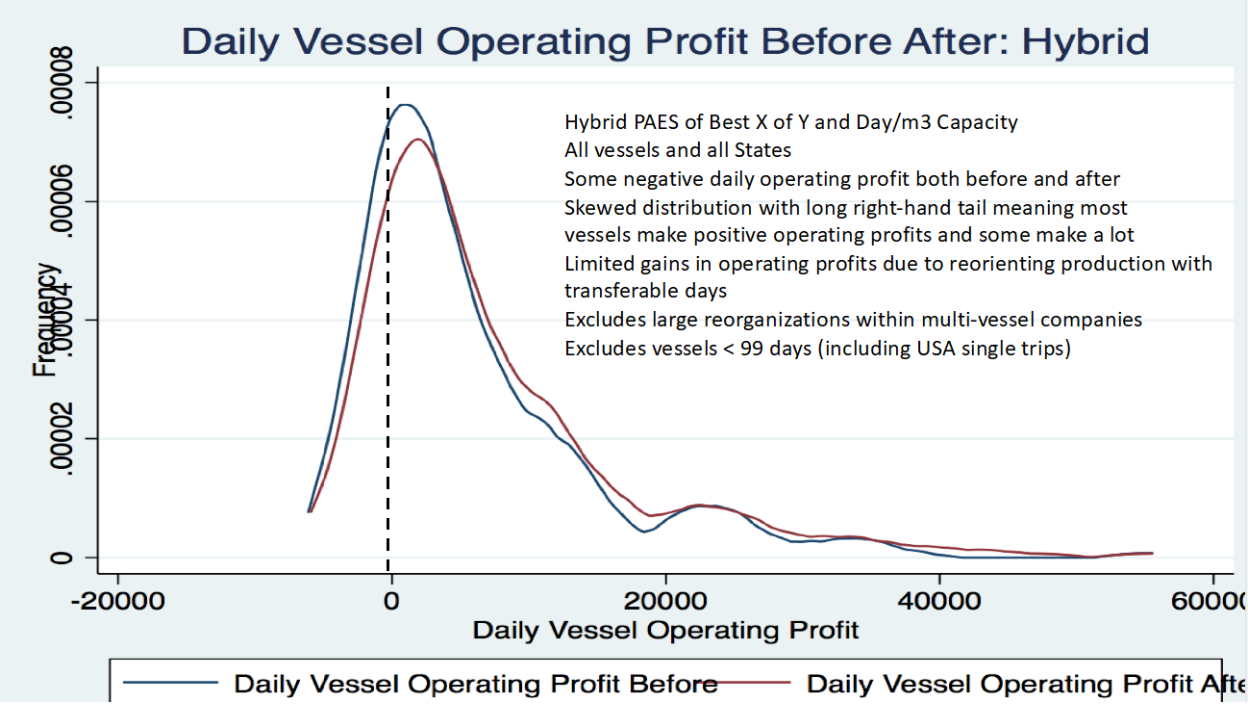
Figure 16C. Proportional Gain in Daily Vessel Operating Profit: *Days/m³ Capacity*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 17A depicts daily vessel operating profit before and after the Scheme for the PAES allocation formulae *Average 3 Years*. The "after" line on the left-hand side of 0 lies inside of the "before" line and lies outside of the "before" line on the right-hand side of 0. The somewhat smaller peak and its slight rightward shift indicate an increase in daily vessel operating profit (vessels were shifted rightward into the right-hand tail). These results indicate that the "after" Scheme daily vessel operating profit exceeds the "before" Scheme daily vessel operating profit.

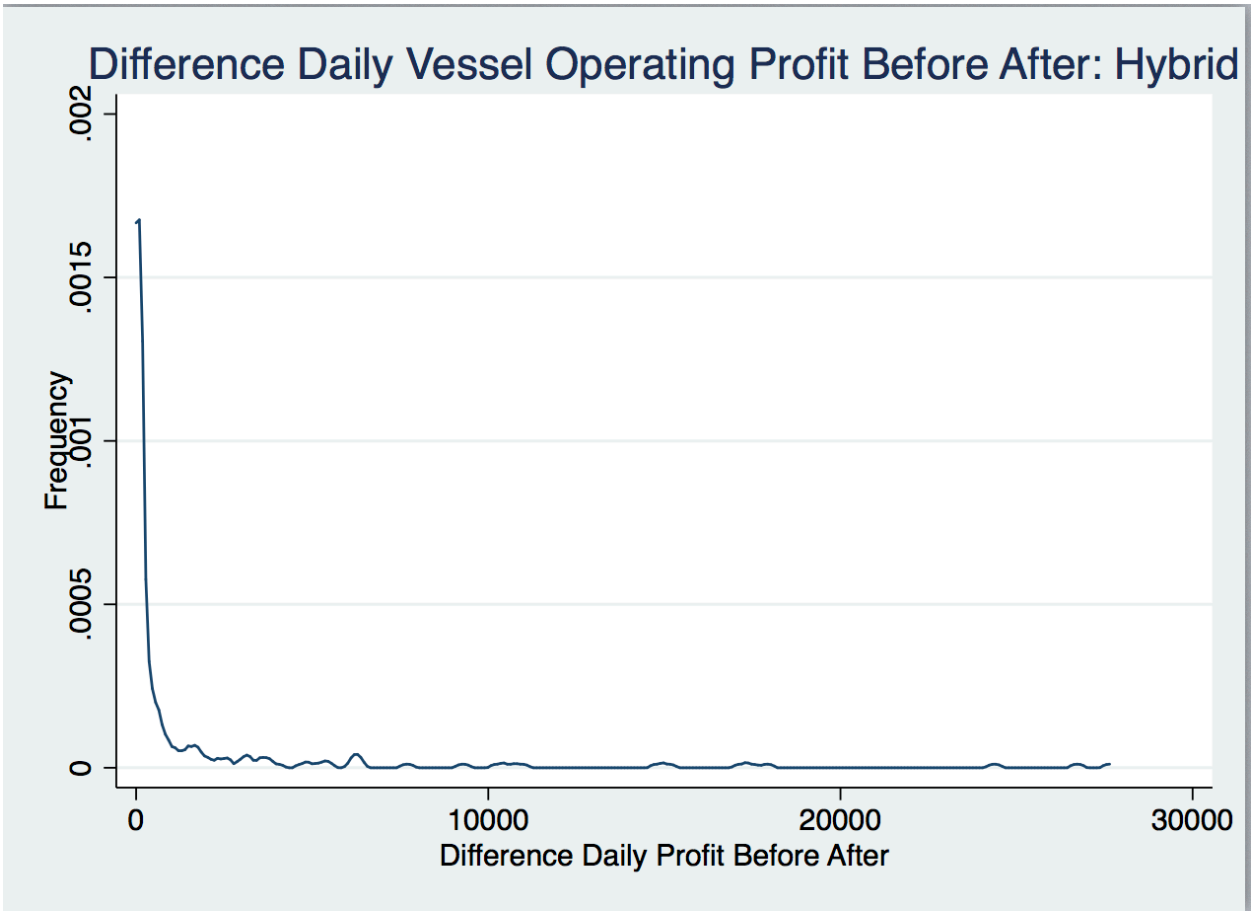
Figure 17A. Daily Vessel Operating Profit Before and After: *Hybrid*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 17B illustrates the difference in vessel daily operating profit before and after the *Best X of Y* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). (This difference is calculated by daily vessel operating profit after the scheme minus before the scheme.) Figure 14B shows that daily vessel operating profit increases due to the Scheme as indicated by the long right-hand tail. Most vessels are bunched together but some vessels enjoy exceptionally large increases in daily vessel operating profit. No vessel is made worse off due to the Scheme.

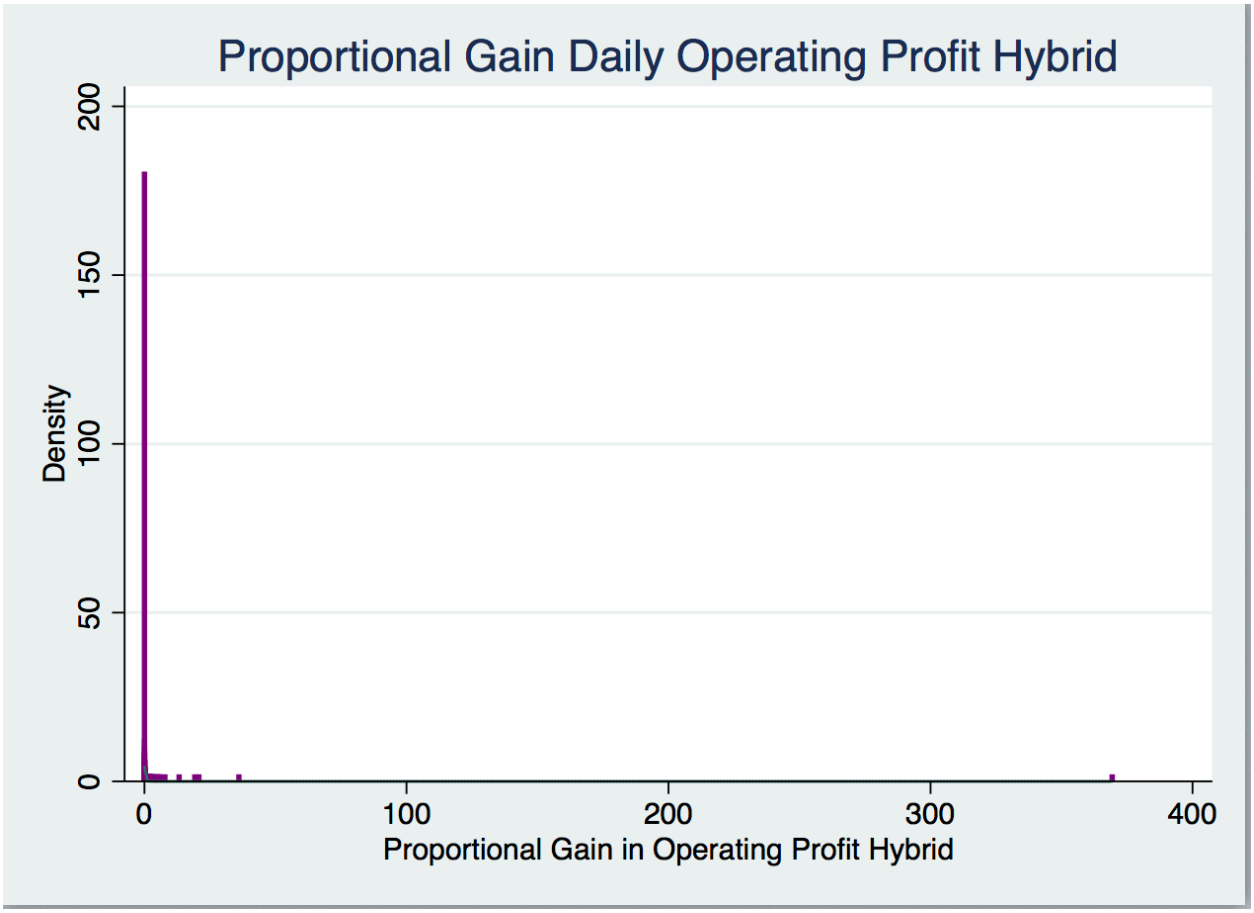
Figure 17B. Difference in Vessel Daily Operating Profit Before and After: *Hybrid*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 17C depicts the proportional gain in daily vessel operating profit for *Hybrid* due to the *Hybrid* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). These results show that daily vessel operating profit increases, some with proportionately large increase, as indicated by the long right-hand tail. Most vessels are bunched together with moderate increases in daily vessel operating profit. No vessel is made worse off due to the Scheme.

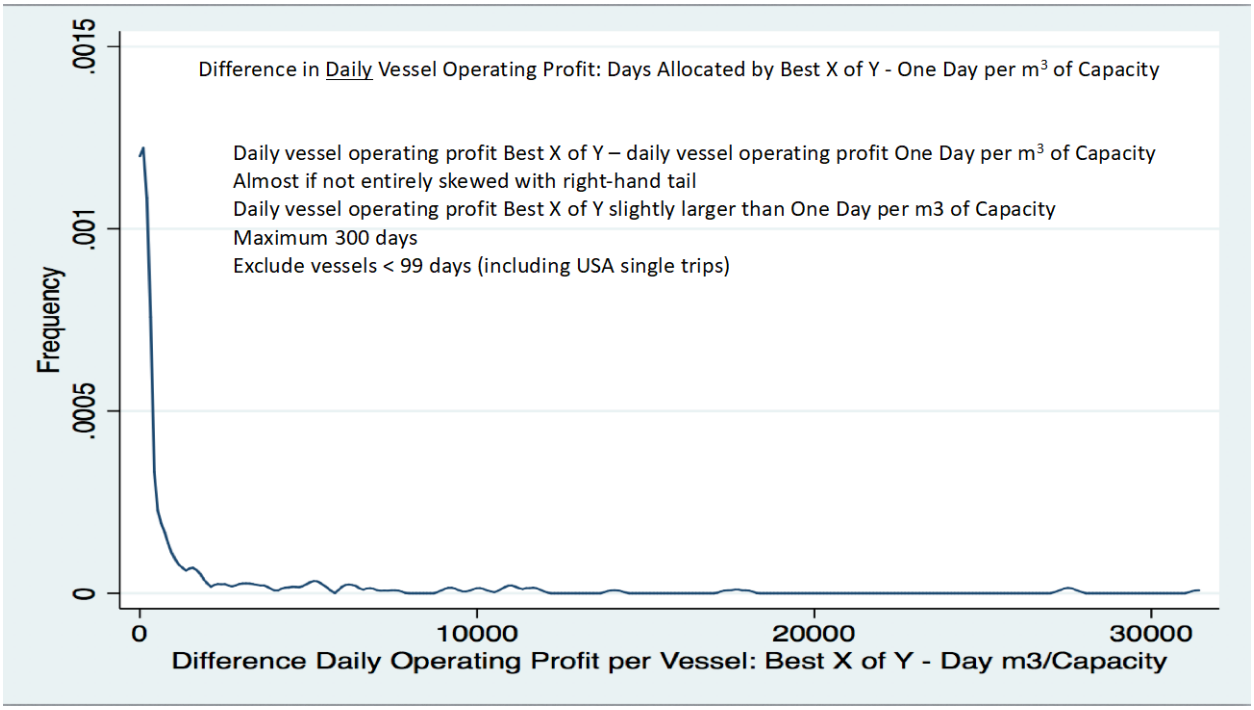
Figure 17C. Proportional Gain in Daily Vessel Operating Profit: *Hybrid*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 18 illustrates the difference in daily vessel operating profit after the transferable day scheme between the *Best X of Y* and *Day/m³ Capacity* PAES (for vessels with at least 99 days). Daily vessel operating profit is almost entirely greater than or equal for the *Best X of Y* compared to *Day/m³ Capacity* PAES. However, the differences are very small, as indicated by the figure starting with a peak at 0 (indicating no difference) and quickly falling to a very small difference (at a positive number not much larger than 0) with a limited number of vessels with very large differences. This result indicates that on average for the entire fleet (with days exceeding 99) both PAES schemes give a similar result.

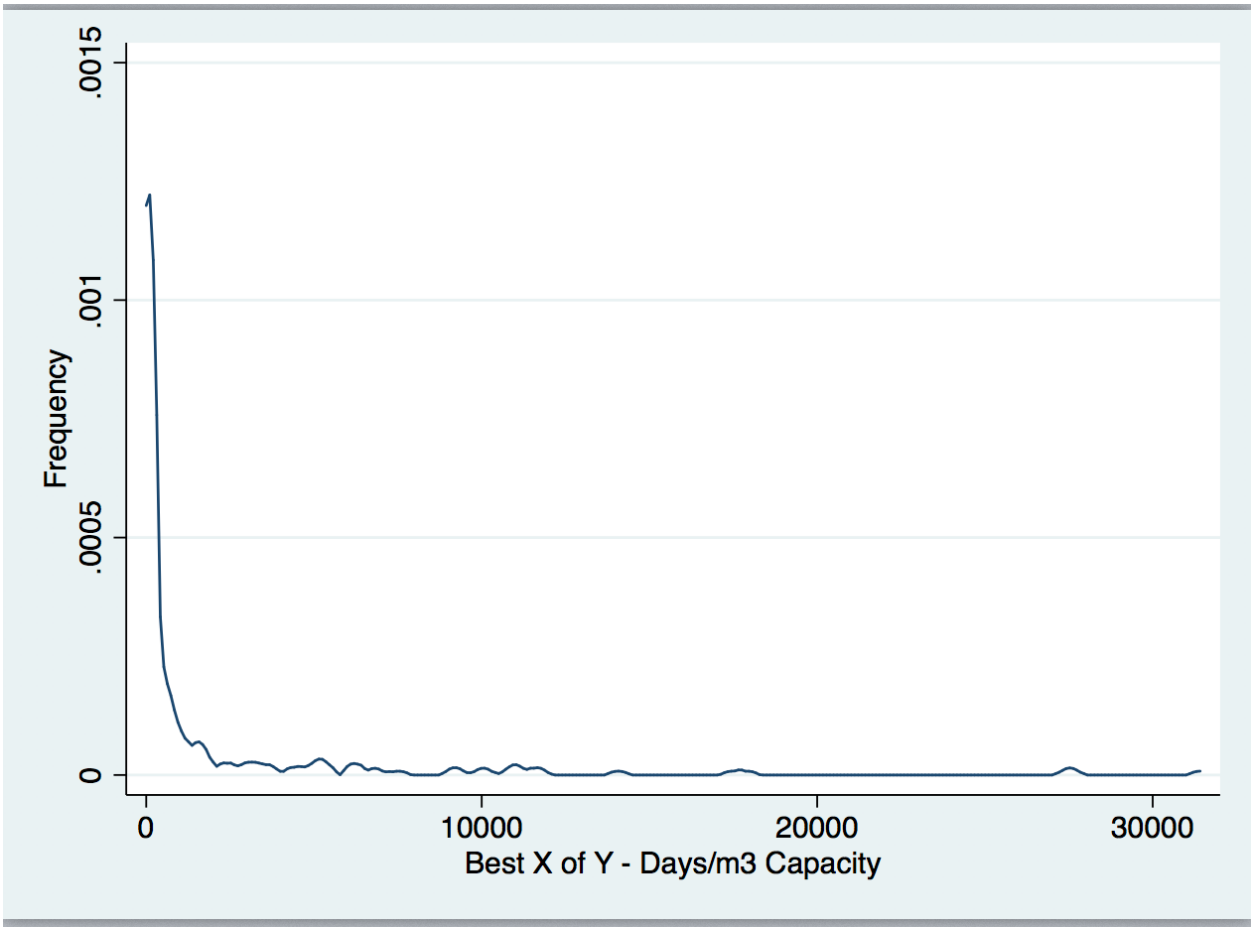
Figure 18. Difference in Vessel Daily Operating Profit After Scheme: *Best X of Y – Days/m³ Capacity*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

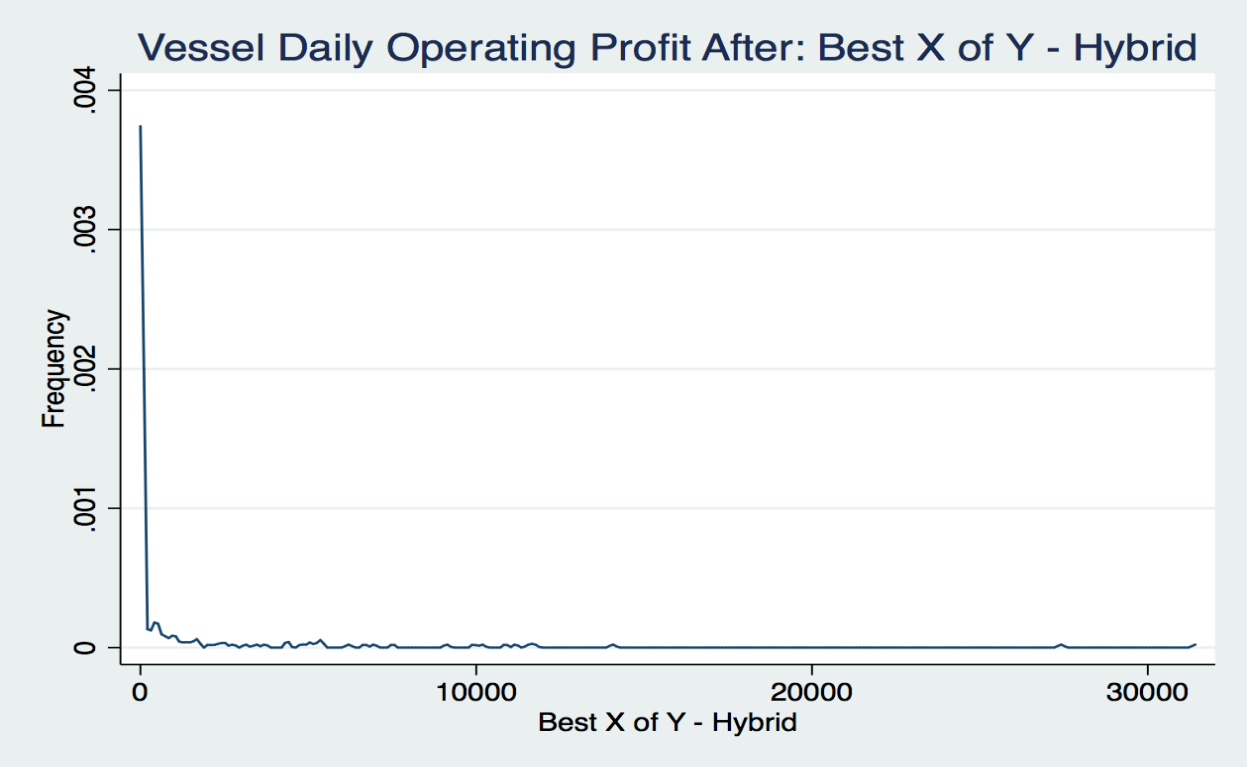
The following Figure 19 illustrates the difference in vessel daily operating profit after the transferable day scheme between the *Best X of Y* and *Hybrid* PAES (for vessels with at least 99 days):

Figure 19. Difference in Daily Vessel Operating Profit After Scheme: *Best X of Y – Hybrid*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

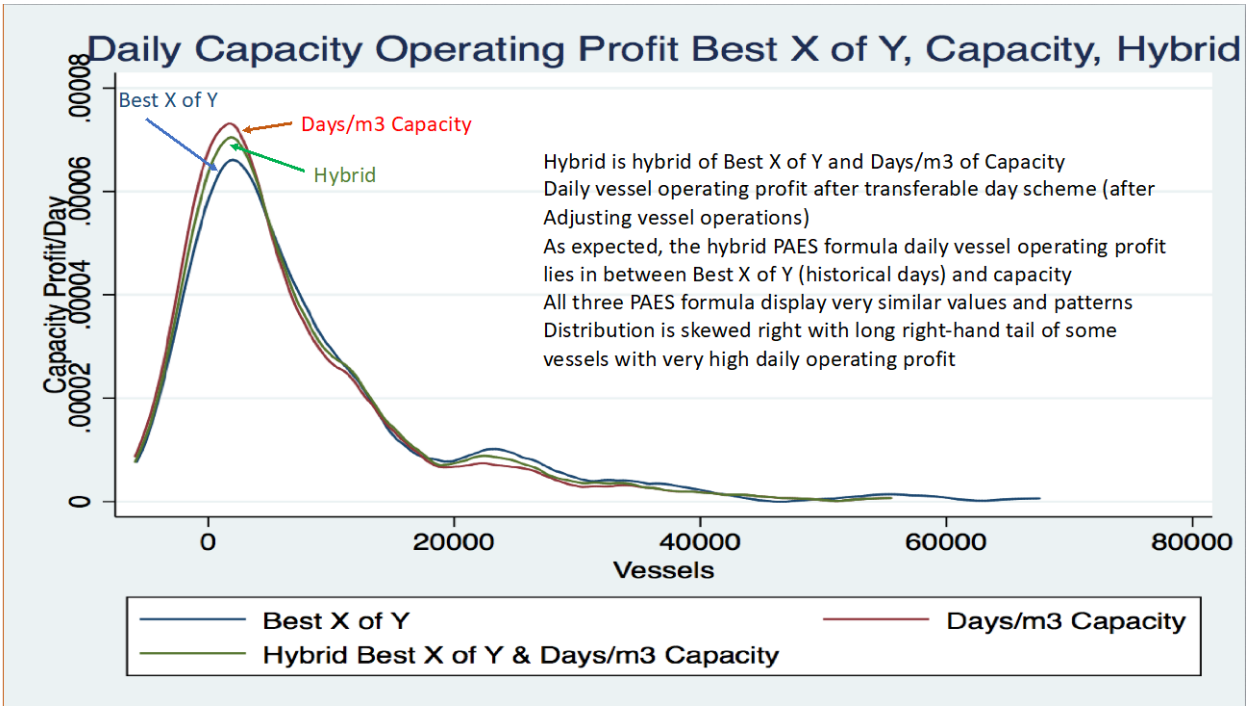
Figure 20. Differences in Daily Vessel Operating Profit After Scheme*: Hybrid – Days/m^3 Capacity*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

Figure 21 following shows daily vessel operating profit after the Scheme for *Best X of Y, Days/m^3 Capacity*, and *Hybrid*. All three are similar with *Hybrid* in between *Best X of Y* and *Days/m^3 Capacity*. Most vessels have positive but small increases following the Scheme but a limited number have very large increases indicated by the skewed distribution with the large right-hand tail.

Figure 21. Daily Vessel Operating Profit After Scheme: *Best X of Y, Days/m^3 Capacity, & Hybrid*



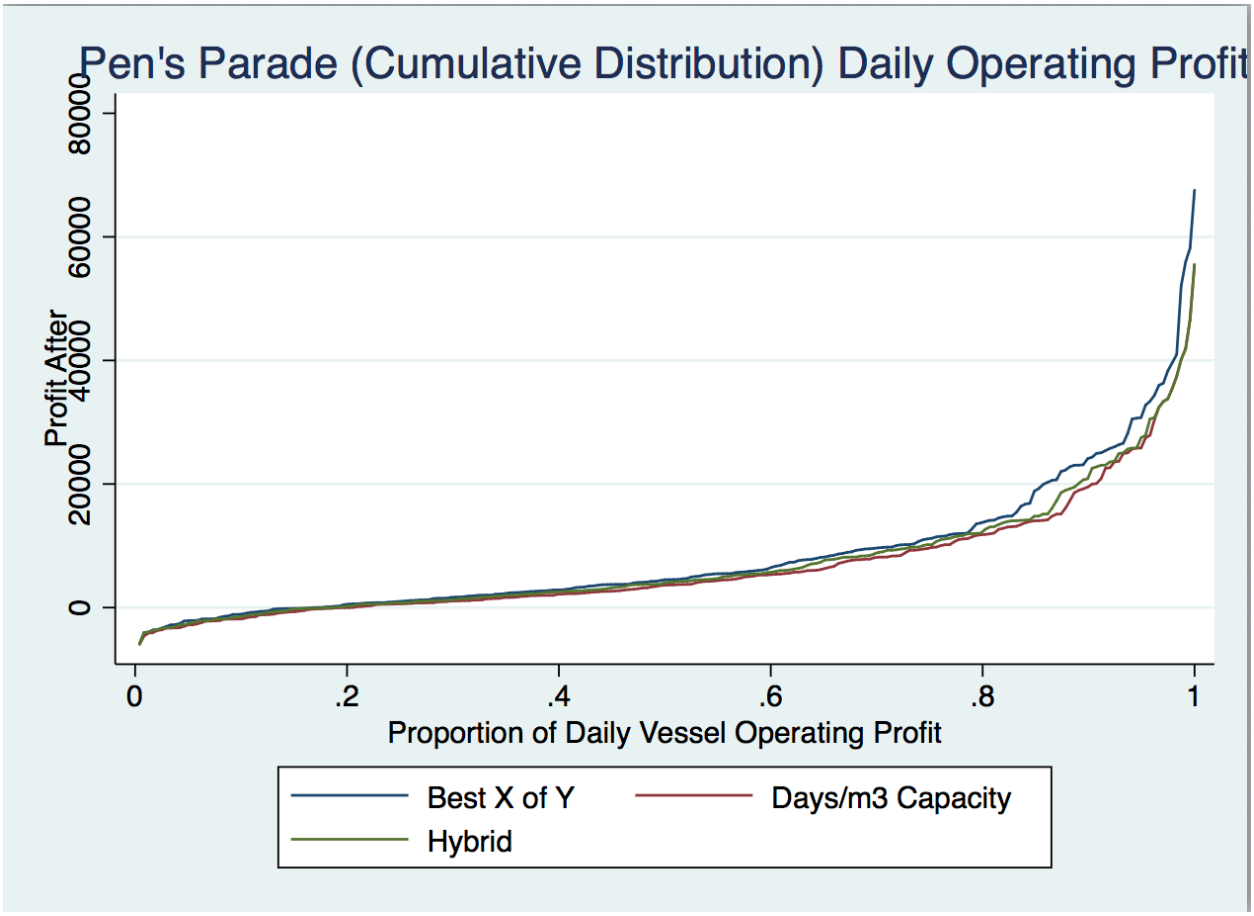
Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

6.1.3. Comparative Speed at Which Vessel Daily Operating Profit Grows: *Best X of Y, Days/m3 Capacity*, & *Hybrid*

The following Figure 22 illustrates "Pen's Parade" or cumulated distribution of daily vessel operating profit after the transferable day credit scheme for the different PAES formulae.[8] The results show that daily vessel operating profit grows at about the same rate until about 80% of vessels have been reached, after which the *Best X of Y* historical days separates to grow faster and to reach a higher maximum.

[8] The figure for "Pen's Parade" or cumulated distribution of daily vessel operating profit after the transferable day credit scheme for the different PAES allocation formulae. Daily vessel operating profit is ordered from the smallest to largest. The smaller daily vessel operating profits are located on the left-hand side of the figure (closer to zero on the horizontal axis). The larger daily vessel operating profit are located on the right-hand side of the figure (closer to one on the horizontal axis). The vertical axis shows the cumulated or summed daily vessel operating profit, where closer to zero on the vertical axis pertains to allocation of only the smaller daily vessel operating profits and the closer to the top of the vertical axis the more daily vessel operating profits are allocated (starting with smaller and ending with larger daily vessel operating profits). The results exclude gains in profit from reorganization within multi-vessel companies.

Figure 21. Pen's Parade Vessel Daily Operating Profit: *Best X of Y, Days/m3 Capacity*, & *Hybrid*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

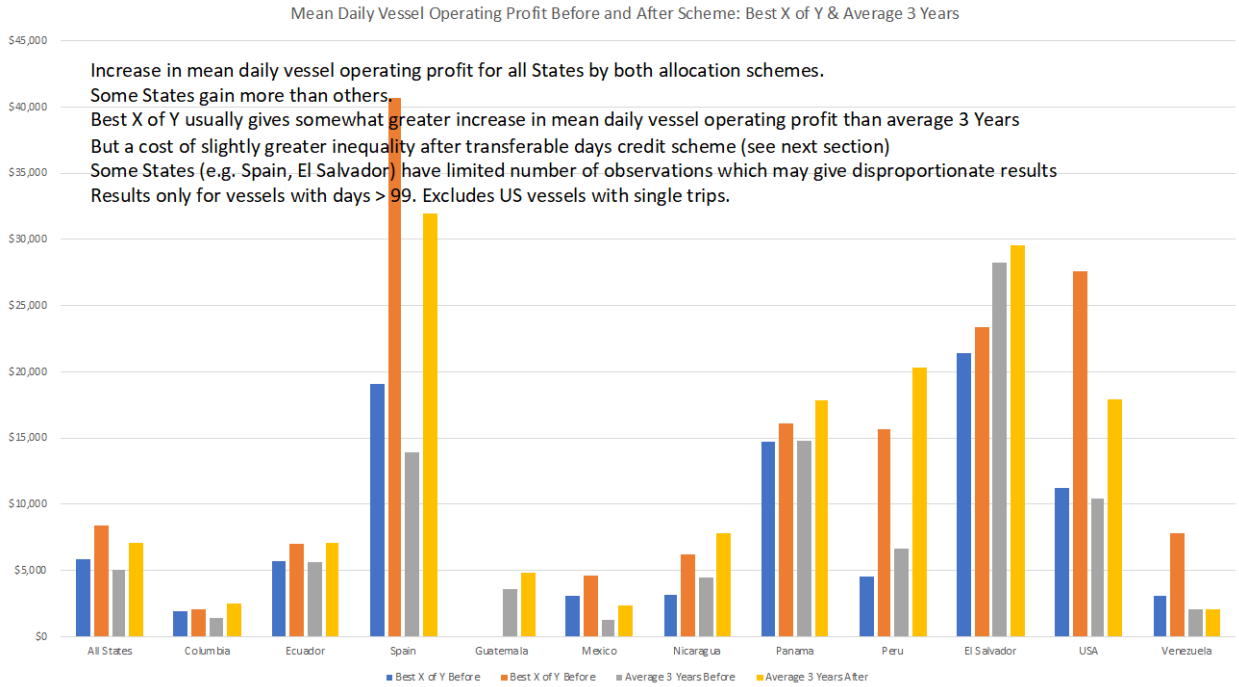
The maximum potential vessel daily operating profit before and after the PAES allocation and transferable credit scheme for *Best X of Y* and *Average 3 Years* by CPC is illustrated by the following Figure 23. The level of daily vessel operating profit varies by CPC, with the vessels of some CPCs enjoying larger profits than the vessels of other CPCs. *Best X of Y* is more profitable for the vessels of some CPCs than *Average 3 Years* and *Average 3 Years* is more profitable for the vessels of other CPCs than *Best X of Y*. The results exclude gains in profit from reorganization within multi-vessel companies.

6.1.4. Mean Daily Vessel Operating Profit Before and After the Scheme by CPC or Capacity Class & DML

Figure 22. Mean Daily Vessel Operating Profit Before and After the Scheme by CPC: *Best X of Y* and *Average 3 Years*

Conclusions for *Best X of Y* and *Average 3 Years*:

- For vessels with days > 99 and excluding US vessels with single trips
- The results exclude gains in profit from reorganization within multi-vessel companies.
- Some CPCs gain more than others
- Best X of Y usually gives somewhat greater in increase in mean daily vessel operating profit than Average 3 Years
- But at a cost of slightly greater inequality after the Scheme
- Some CPCs (e.g. Spain, El Salvador) have a limited number of observations that may give disproportionate results



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. The results exclude gains in profit from reorganization within multi-vessel companies.

The following Table 4 and Figure 23 show the mean daily vessel operating profit before and after the Scheme for *Best X of Y* and *Average 3 Years*.

Table 4. Mean Daily Vessel Operating Profit Before-and-After Transferable Day Credit Scheme: *Best X of Y* and *Average 3 Years*

Mean Daily Vessel Operating Profit Before-and-After Transferable Day Credit Scheme: Best X of Y and Average 3 Years

State	Mean Daily Operating Profit per Vessel Before Best X of Y	Mean Daily Operating Profit per Vessel Before Average 3 Years	Mean Daily Operating Profit per Vessel After Best X of Y	Mean Daily Operating Profit per Vessel After Average 3 Years
All States	$5,843	$5,037	$8,367	$7,097
Columbia	$1,906	$ 1,422	$2,015	$2,447
Ecuador	$5,753	$5,620	$6,980	$7,080
Spain	$19,113	$13,928	$40,682	$31,911
Guatemala		$3,572		$4,817
Mexico	$3,073	$1,313	$4,589	$2,379
Nicaragua	$3,174	$4,425	$6,199	$7,822
Panama	$14,717	$14,804	$16,049	$17,801
Peru	$4,568	$6,595	$15,661	$20,256
El Salvador	$21,321	$28,218	$23,361	$29,548
USA	$11,227	$10,451	$27,562	$17,916
Venezuela	$3,007	$2,089	$7,806	$2,089

Note excludes vessels with < 99 days (including USA single trips). Manta prices averaged over 2016-2018. US$2019. Some States have very limited number of observations, giving unreliable estimates.

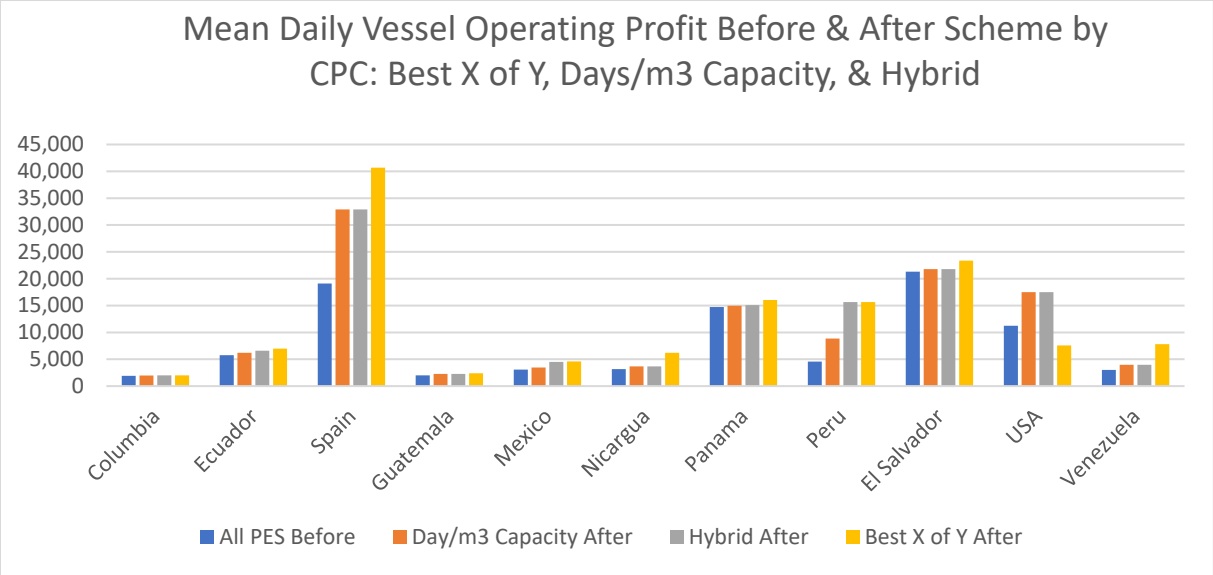
Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. Excludes gains in daily vessel operating profit due to reorganizations within multi-vessel Companies.

The following Figure 23 shows mean daily vessel operating profit from before compared to after the Scheme for *Best X of Y, Days/m3 Capacity* and *Hybrid* by CPC.

Conclusions Mean Daily Vessel Operating Profit Before and After the Scheme by CPC: *Best X of Y*, *Days/m^3 Capacity* and *Hybrid:*

- The level of profit varies by CPC, with the vessels of some CPCs enjoying larger profits than the vessels of other CPCs.
- All CPCs enjoy an increase in profitability under the Scheme for all alternative PAES allocation methods with the exception of the USA that loses profitability for Best X of Y.
    - That is, the USA due to its unique arrange for vessel trips from the Western and Central Pacific loses profitability for a PAES allocation based upon historical days.
- Some CPCs gain in mean daily vessel operating profit more than others due to the Scheme
- The results exclude gains in profit from reorganization within multi-vessel companies.

Figure 23. Mean Daily Vessel Operating Profit Before and After the Scheme by CPC: *Best X of Y, Days/m^3 Capacity* and *Hybrid*



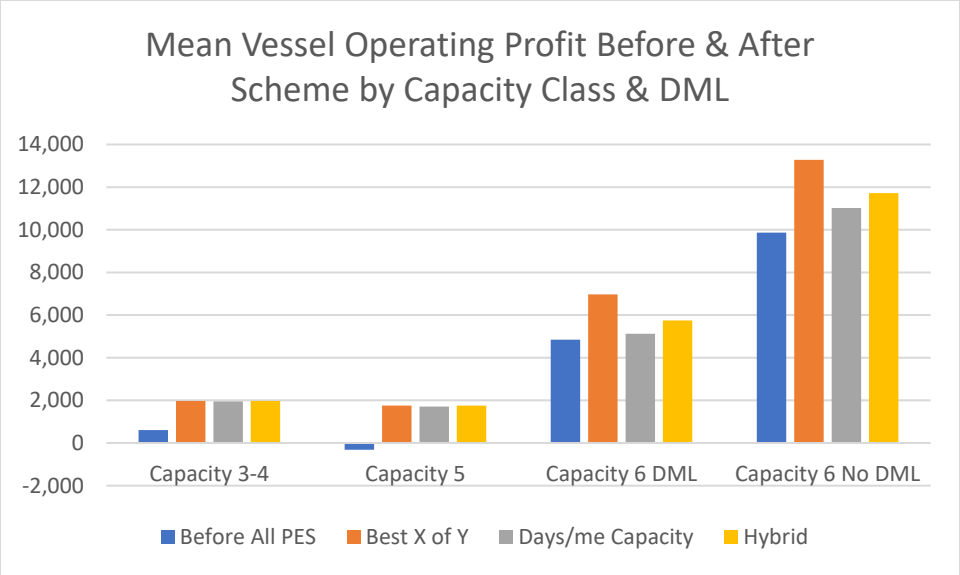
Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. The results exclude gains in profit from reorganization within multi-vessel companies.

The following Figure 24 shows mean daily vessel operating profit from before compared to after the Scheme for *Best X of Y, Days/m3 Capacity* and *Hybrid* by capacity class where capacity class 6 is distinguished by whether not the vessel holds a DML.

Conclusions Mean Daily Vessel Operating Profit Before and After: *Best X of Y, Days/m3 Capacity* and *Hybrid:*

- All categories increase daily vessel operating profit due to the Scheme.
- Capacity Classes 3-4 and 5 have relatively small mean daily operating profit, with Capacity Class 5 facing negative profit prior to the Scheme.
- Capacity Class 6 DML vessels have lower mean daily vessel operating profit than Capacity Class 6 without DML vessels
    - Could potentially be due to lower ex-vessel transfer prices in vertically integrated seafood companies.
- Capacity 6 vessels without DMLs enjoy the highest mean profitability.
- *Best X of Y, Days/3 Capacity*, and *Hybrid* all have very similar impacts upon increased profitability for Class 4-5 and Class 5 vessels.
- For Class 6 vessels, with and without DMLs, the order of increased profitability due to the Scheme from highest to lowest is: *Best X of Y* > *Hybrid* > *Days/m^3 Capacity*.

Figure 24. Mean Daily Vessel Operating Profit Before and After the Scheme by Capacity Class & DML: *Days/m^3 Capacity* and *Hybrid*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. The results exclude gains in profit from reorganization within multi-vessel companies.

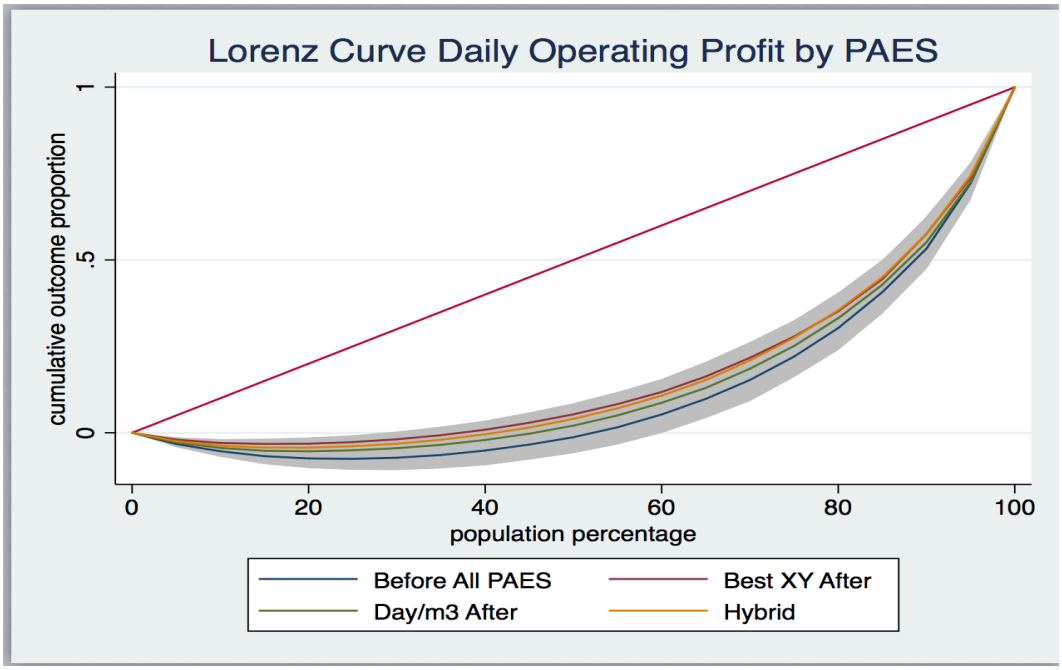
7. Equity: Daily Vessel Operating Profit

7.1. Lorenz Curve for Equity in Daily Vessel Operating Profit

The Lorenz Curve here is a graphical representation of distribution of daily vessel operating profit within a population of vessels. The Lorenz Curve plots cumulated percentiles of the vessels on the horizontal axis according to daily vessel operating profit and plots cumulative daily vessel operating profit on the vertical axis. The 45-degree line represents perfect equality and the further from the 45-degree line the greater the inequality.

Figure 26 depicts the Lorenz Curve for daily vessel operating profit before the PAES allocation and Scheme and after the PAES allocation and Scheme for *Best X of Y*, *Days/m^3 Capacity*, & *Hybrid.* All lines are very close to one another but are statistically significant in their differences, indicating very similar but nonetheless distinct levels of equality. The slight ranking is in terms of highest to lowest equality is: *Best X of Y* > *Hybrid* > *Days/m^3 Capacity* > *Before*. This ranking indicates that the Scheme very slightly increased equality in distribution of daily vessel operating profit among vessels and that the different PAES allocation formulae give slightly different levels of equality in daily vessel operating profit.

Figure 25. Lorenz Curve Daily Vessel Operating Profit: Before All PAES, *Best X of Y*, *Days/m^3 Capacity*, & *Hybrid*



Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. The results exclude gains in profit from reorganization within multi-vessel companies.

7.2. Equity Metrics for Daily Vessel Operating Profit

Conclusions on equity of distribution of daily vessel operating profit:

- All four alternative ways to allocate PAES give a high degree of equity according to standard equity metrics.
- The ranking in equity from highest equity to lowest equity is: *Hybrid* > *Best X of Y* > *Average 3 Years* > *Days/m^3 Capacity*
- The differences between different PAES formulae are statistically significant and very slight
- There is less equity across all vessels and States than for total revenue, i.e. vessel daily operating profit is less equitably distributed across all vessels and States than total revenue, reflecting differences in vessel daily operating costs

Table 5. Equity Metrics for Vessel Operating Profit with Different PAES

Type of PAES Allocation	Gini Coefficient	Ratio of 90th Percentile to 10th Percentile	Theil's Generalized Entropy GE(1)	Atkinson's Inequality Measure (γ=1)
Before PAES Allocation and Scheme	0.52894	28.424	0.47446	0.46828

After Scheme				
Average 3 Years	0.51651	19.419	0.45094	0.43520
Best X of Y	0.53698	25.323	0.49293	0.47350
Days/m³ Capacity	0.53586	26.913	0.48782	0.46149
Hybrid	0.52724	24.092	0.46988	0.46316

Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. The results exclude gains in profit from reorganization within multi-vessel companies.
Average 3 Years is calculated from different data than the other three PAES formulae
Atkinson: Lower values more equal, $0 \leq A(\gamma = 1) \leq 1$. Atkinson can be interpreted as the percentage of per capita "income" (here daily vessel operating profit per vessel) that would provide the same total welfare as the actual "income" if it were equally distributed.
Gini Coefficient: Lower values more equal, $0 \leq G \leq 1$.
Theil's Generalized Entropy: Lower values more equal, $0 \leq GE(1) \leq \infty$.

7.2.1. Equity – Efficiency Trade-Offs: Daily Vessel Operating Profit

The following Table 6 and its Figure 26 summarize the equity-efficiency trade-offs between the four different PAES allocation formulae.

Table 6. Summary of Economic Efficiency and Equity by PAES Allocation Type

Type of PAES Allocation	Mean Daily Vessel Operating Profit (US$)	Rank of Profitability Highest to Lowest	Atkinson's Inequality Measure (γ=1)	Rank of Equality Highest to Lowest
Average 3 Years	7,097	3	0.43520	2
Best X of Y	8,367	1	0.47350	4
Days/m³ Capacity	6,733	4	0.46149	3
Hybrid	7,265	2	0.46316	1

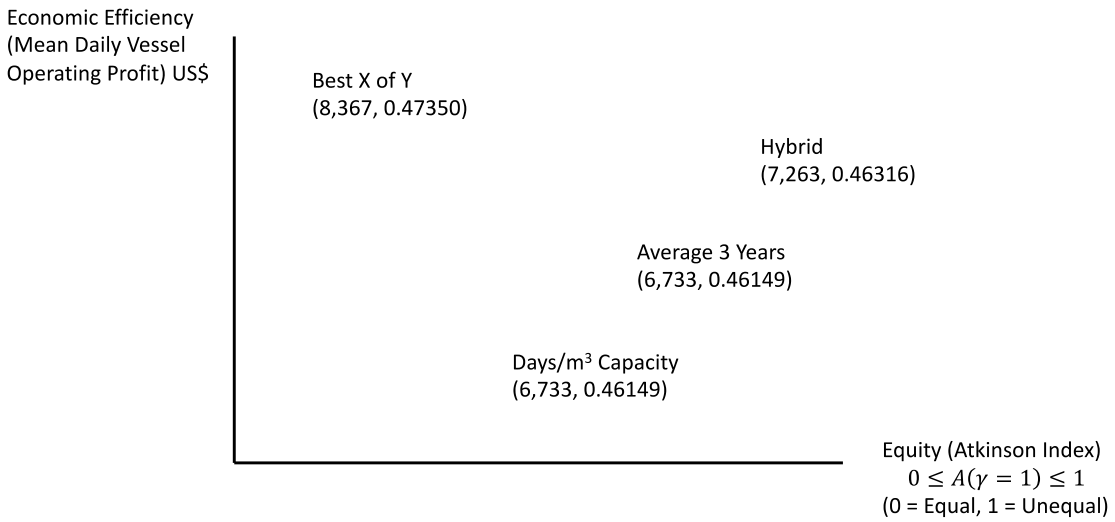
Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. The results exclude gains in profit from reorganization within multi-vessel companies.
Average 3 Years is calculated from different data than the other three PAES formulae
Atkinson: Lower values more equal, $0 \leq A(\gamma = 1) \leq 1$.

The following Figure 26 depicts the equity-efficiency trade-off after the Scheme for daily vessel operating profit and depicts Table 5. The higher on the figure the more efficient in terms of daily vessel operating profit and the more to the right-hand side the greater the equality of distribution among vessels of daily vessel operating profit.

Conclusions on Equity-Efficiency Trade-Off After the Scheme:

- Best X of Y is the most efficient and least equitable.
- Hybrid is second most efficient and most equitable.
- The differences in equity between different PAES formulae is very slight.
- Hybrid is fair on two accounts: once when the IATTC chooses a PAES formulae and second when vessels choose between *Best X of Y* and *Days/m^3 Capacity*.

Figure 26. Equity-Efficiency Trade-Off Among Vessels



8. Total Revenue

This section evaluates the efficiency gains and equity impacts in terms of daily vessel total for the alternative PAES allocation schemes. Total revenue is individually calculated for each vessel using IATTC landings data and species-specific average monthly ex-vessel landings prices sourced from Ecuador.

This analysis is short-run because it does not include consolidation of days among multi-vessel companies and accompanying savings in fixed costs. This consolidation of days likely leads to a large increase in profitability. The analysis provides the maximum potential gains because the analysis assumes perfect transferability of credits without costs of information, transactions, CPC Flag State transfers, plus constant prices and constant catch per unit of effort.

A separate analysis of the Ecuador ex-vessel tuna market shows that there can be slight revenue gains by shifting harvests to the first quarter of the year, but the results are very small; the impact of shifting landings to different times of the year is very small.

The analysis excludes vessels with fewer than 99 days for vessels without a DML because such vessels are visibly different and including them led to nonsensical quantitative results. These vessels included the single trips for US vessels allowed from the Western and Central Pacific and some Peruvian and Ecuadorian vessels. These vessels were assumed to be qualitatively different (e.g. different behavioral objectives or having been subject to mechanical issues, etc.) from the other vessels and were thus excluded from the analysis. Of the 18 excluded non-DML vessels in the *Best X of Y* allocation, 10 were US vessels. Two DML vessels had fewer than 99 days, but were included in the analysis since their inclusion did not visibly impact the analysis.

8.1. Mean Daily Vessel Total Revenue Before and After Scheme

Table 7 shows the mean daily vessel total revenue before and after the pilot Transferable Day Credit Scheme for *Average 3 Years*, *Best X of Y, Days/m3 Capacity*, and *Hybrid*.

Conclusions:

- Highest daily vessel total revenue after Scheme ranked from highest to lowest:
  - *Best X of Y > Average 3 Years > Hybrid > Days/m3 Capacity*
- Highest percent gain in daily total revenue due to Scheme ranked from highest to lowest:
  - *Best X of Y > Average 3 Years > Hybrid > Days/m3 Capacity*

Table 7. Summary Statistics Daily Vessel Total Revenue ($)

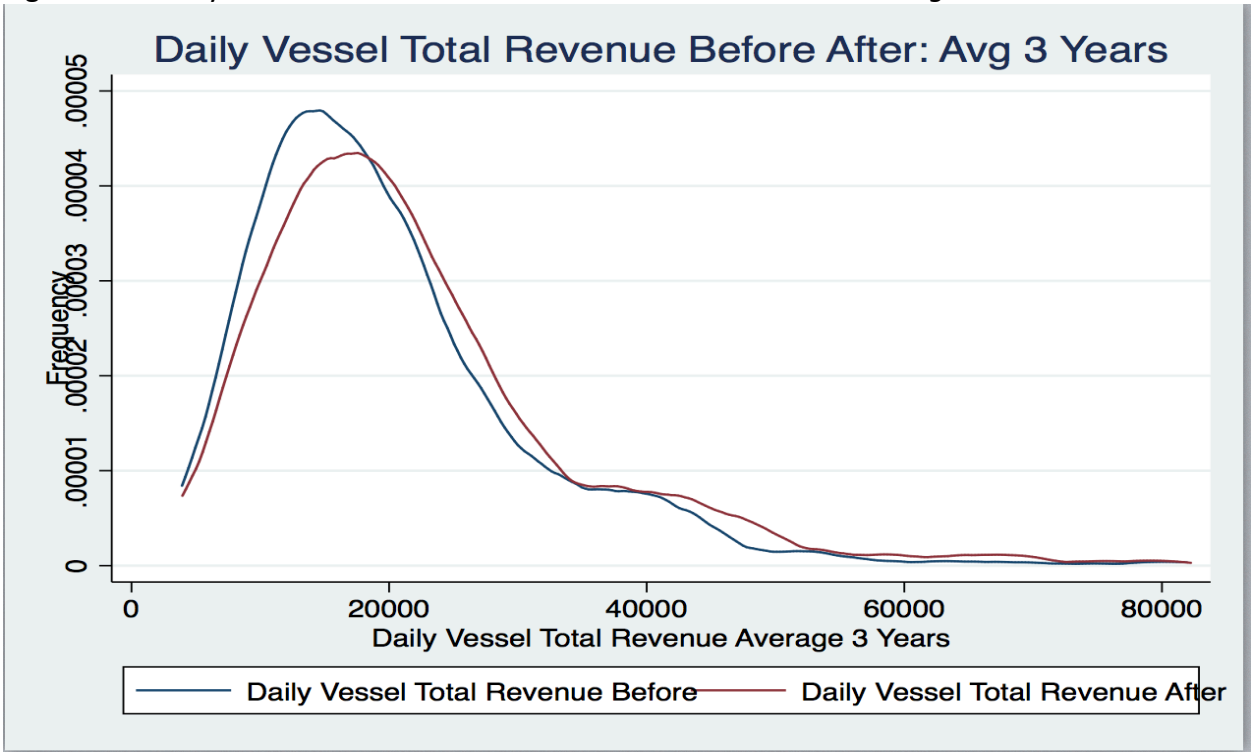
Type of PAES Allocation	Mean	Standard Deviation
Before:		
Average 3 Years	19,933	10,969
Best X of Y	20,534	10,1967
Days/m^3 Capacity	20,534	10,1967
Hybrid	20,534	10,1967
After:		
Average 3 Years	22,003	12,293
Best X of Y	23,058	12,495
Days/m^3 Capacity	21,424	10,789
Hybrid	21,954	10,900
% Gain		
Average 3 Years	11.02	0.1852249
Best X of Y	14.58	0.3996459
Days/m^3 Capacity	6.52	0.3068319

Hybrid	9.95	0.3527731

Note: Vessel's days > 99.
Average 3 Years calculated from different data than the other PAES allocation formulae.
Differences calculated directly from individual vessel observations.
Excludes gains in daily vessel total revenue due to reorganizations within multi-vessel Companies.

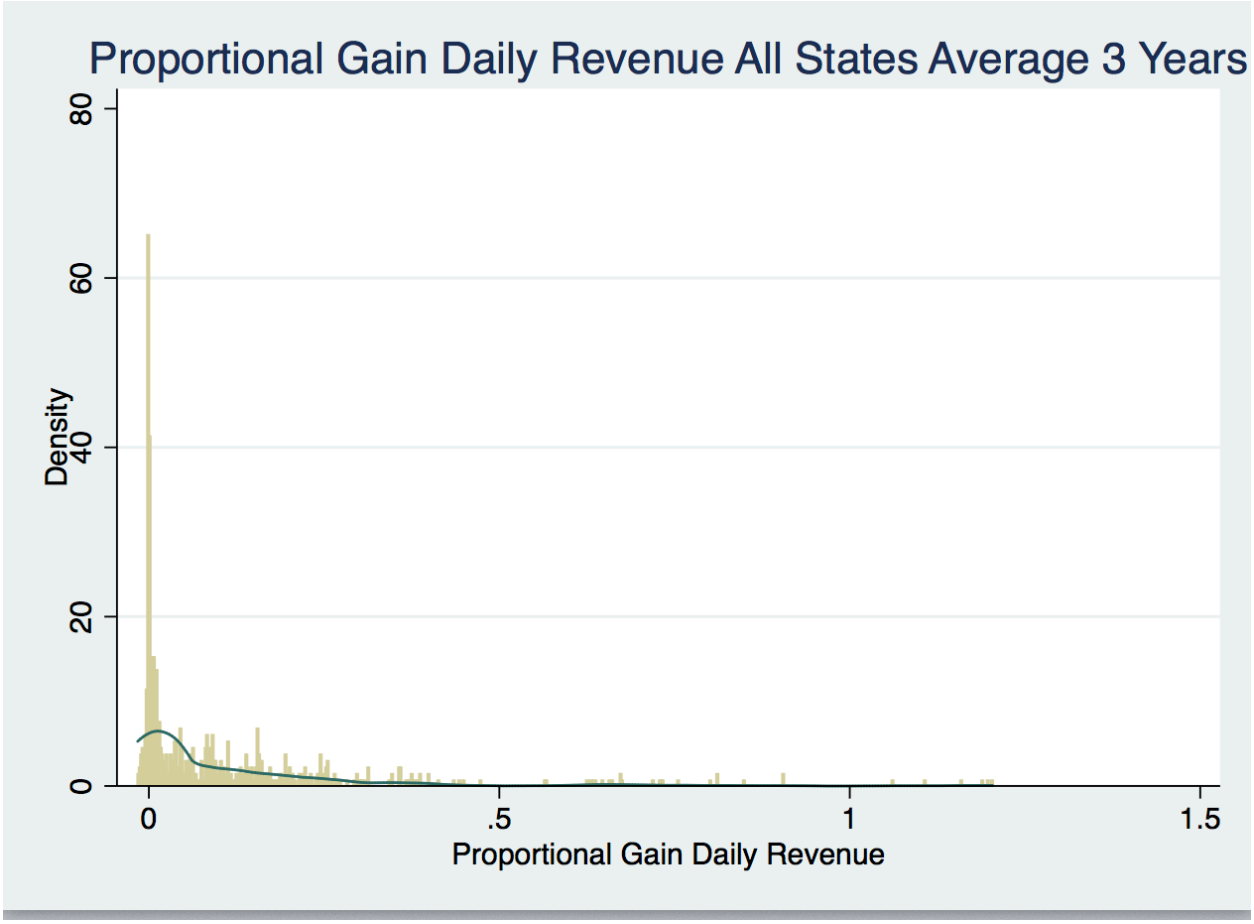
The following Figure 27A depicts daily vessel total before and after the Scheme for the PAES allocation formulae *Average 3 Years*. The "after" line on the left-hand side of 0 lies inside of the "before" line and lies outside of the "before" line on the right-hand side of 0. The somewhat smaller peak and its slight rightward shift indicate an increase in daily vessel total revenue (vessels were shifted rightward into the right-hand tail). These results indicate that the "after" Scheme daily vessel total exceeds the "before" Scheme daily vessel total revenue.

Figure 27A. Daily Vessel Total Revenue Before and After Scheme: *Average 3 Years*



The following Figure 27B depicts the proportional gain in daily vessel total revenue for *Average 3 Years* due to the *Average 3 Years* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). These results show that daily vessel total revenue increases, some with proportionately large increase, as indicated by the long right-hand tail. Most vessels are bunched together with moderate increases in daily vessel total revenue.

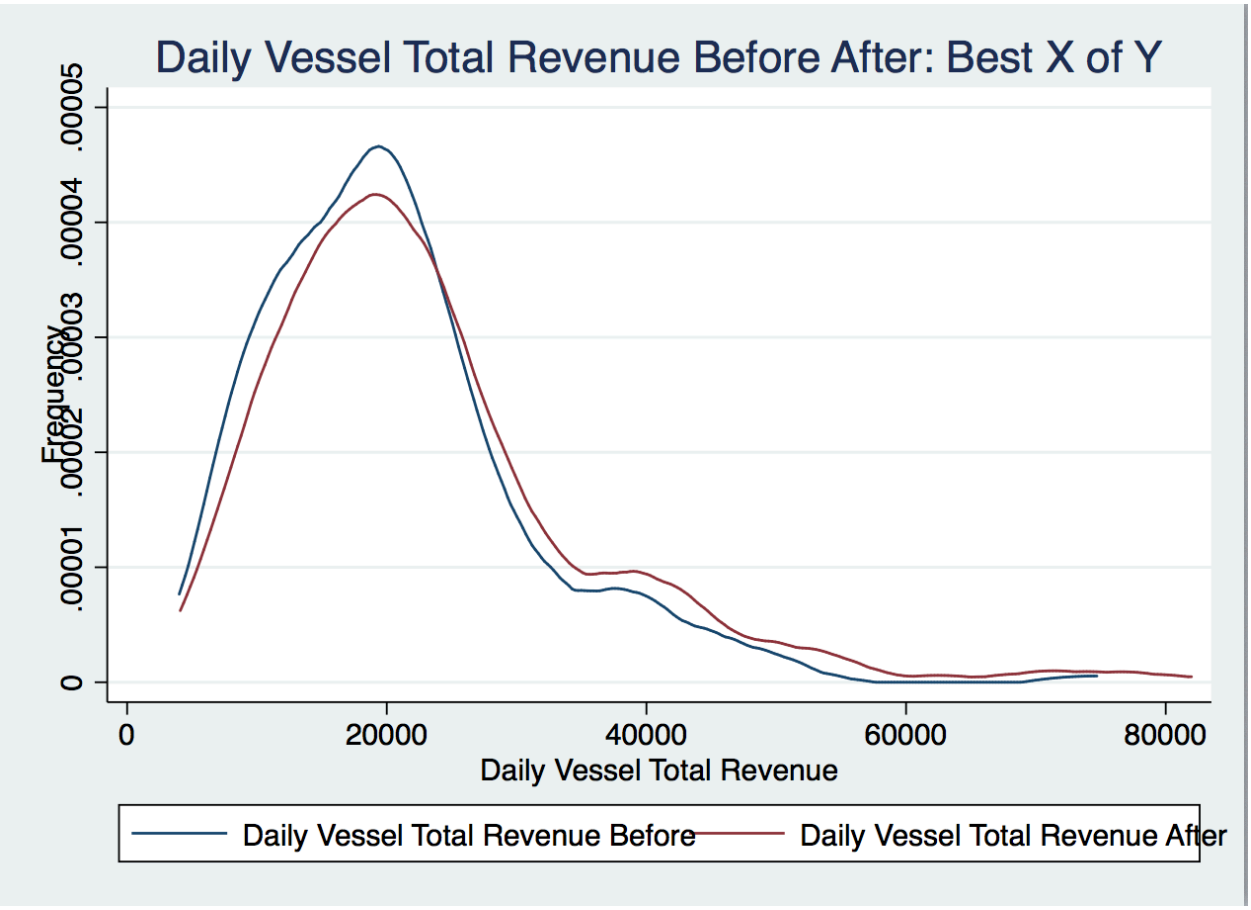
Figure 27B. Proportional Gain in Daily Vessel Revenue All States: *Average 3 Years*



Note: Vessel's days > 99. The results exclude gains in profit from reorganization within multi-vessel companies.

Figure 28A depicts daily vessel total revenue before and after the Scheme for *Best X of Y*. It shows that this revenue tends increases due to the Scheme since the left-hand tail of the "before" exceeds the left-hand-tail of the "after" (because is more frequent before for these smaller values) and the right-hand tail of the "after" exceeds the right-hand tail of the "before" (since there are now more vessels with higher total revenues following the Scheme).

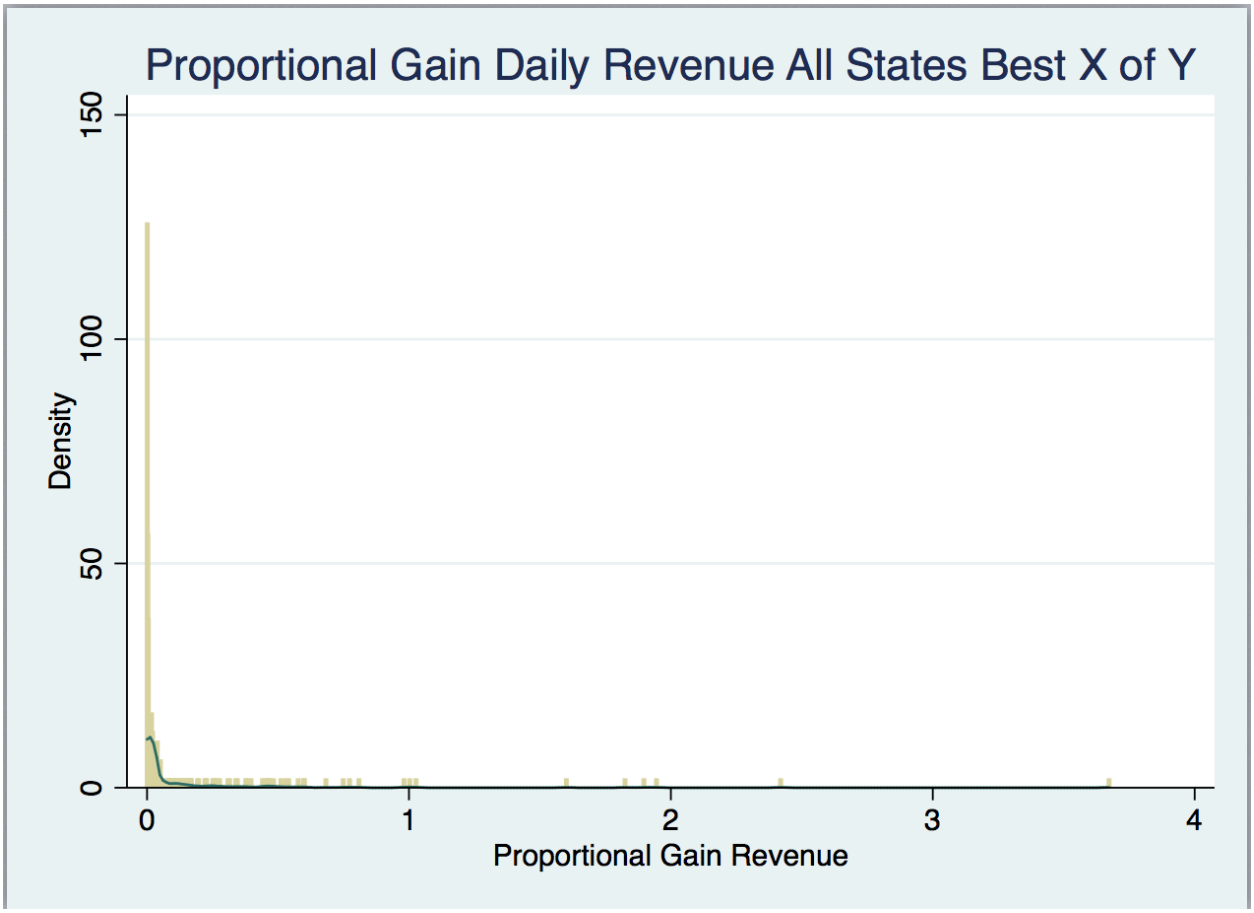
Figure 28A. Daily Vessel Total Revenue Before and After Scheme: *Best X of Y*



Note: Vessel's days > 99. The results exclude gains in profit from reorganization within multi-vessel companies.

The following Figure 28B depicts the proportional gain in daily vessel total revenue for *Average 3 Years* due to the *Best X of Y* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). These results show that daily vessel total revenue increases, some with proportionately large increase, as indicated by the long right-hand tail. Most vessels are bunched together with moderate increases in daily vessel total revenue. No vessel is made worse off due to the Scheme.

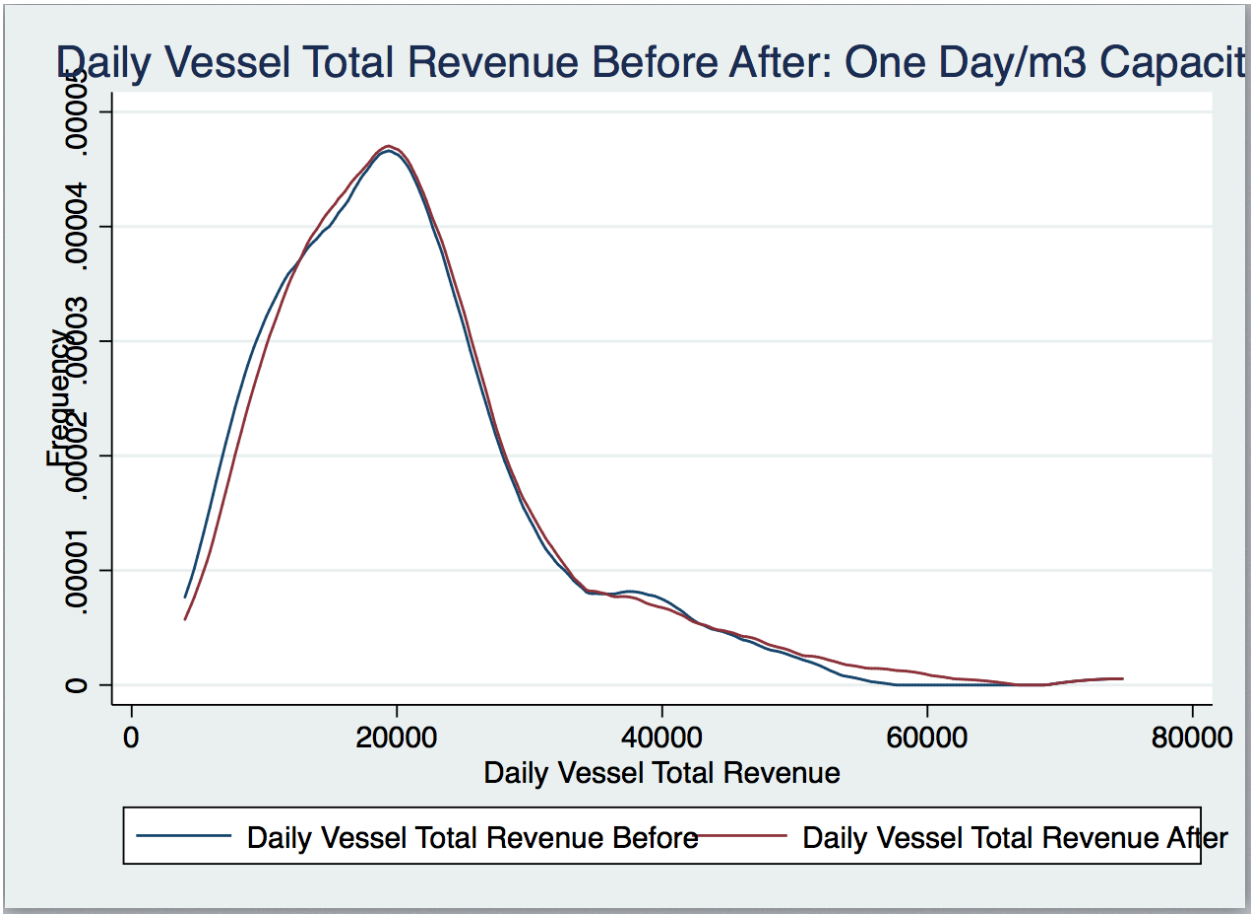
Figure 28B. Proportional Gain in Daily Vessel Revenue All States: *Best X of Y*



Note: Vessel's days > 99. The results exclude gains in profit from reorganization within multi-vessel companies.

Figure 29A depicts daily vessel total revenue before and after the Scheme for *Days/m^3 Capacity*. It shows that this revenue tends increases due to the Scheme since the left-hand tail of the "before" exceeds the left-hand-tail of the "after" (because is more frequent before for these smaller values) and the right-hand tail of the "after" exceeds the right-hand tail of the "before" (since there are now more vessels with higher total revenues following the Scheme).

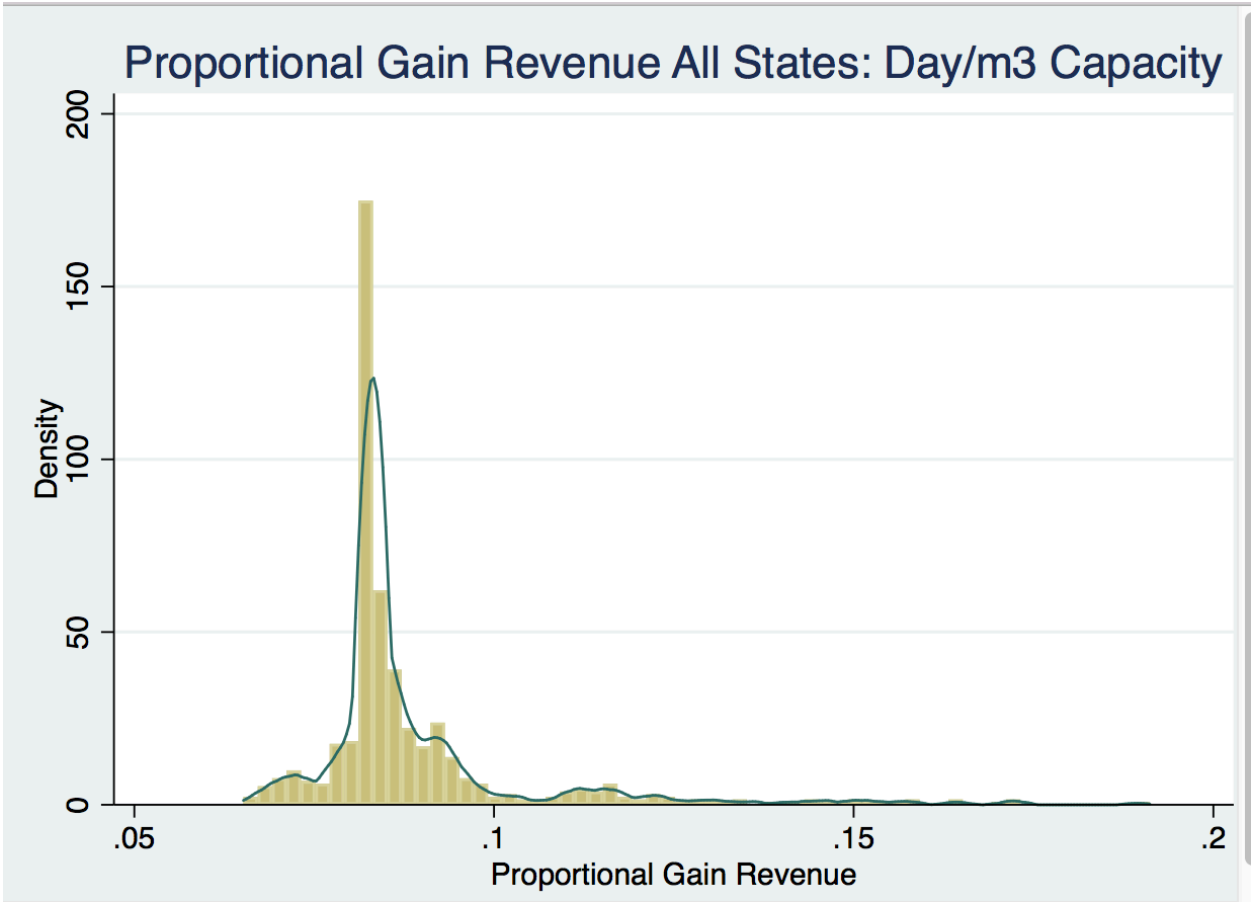
Figure 29A. Daily Vessel Total Revenue Before and After Scheme: *Days/m^3 Capacity*



Note: Vessel's days > 99. The results exclude gains in profit from reorganization within multi-vessel companies.

The following Figure 29B depicts the proportional gain in daily vessel total revenue for *Average 3 Years* due to the *Days/m^3 Capacity* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). These results show that daily vessel total revenue increases, some with proportionately large increase, as indicated by the long right-hand tail. Most vessels are bunched together with moderate increases in daily vessel total revenue. No vessel is made worse off due to the Scheme.

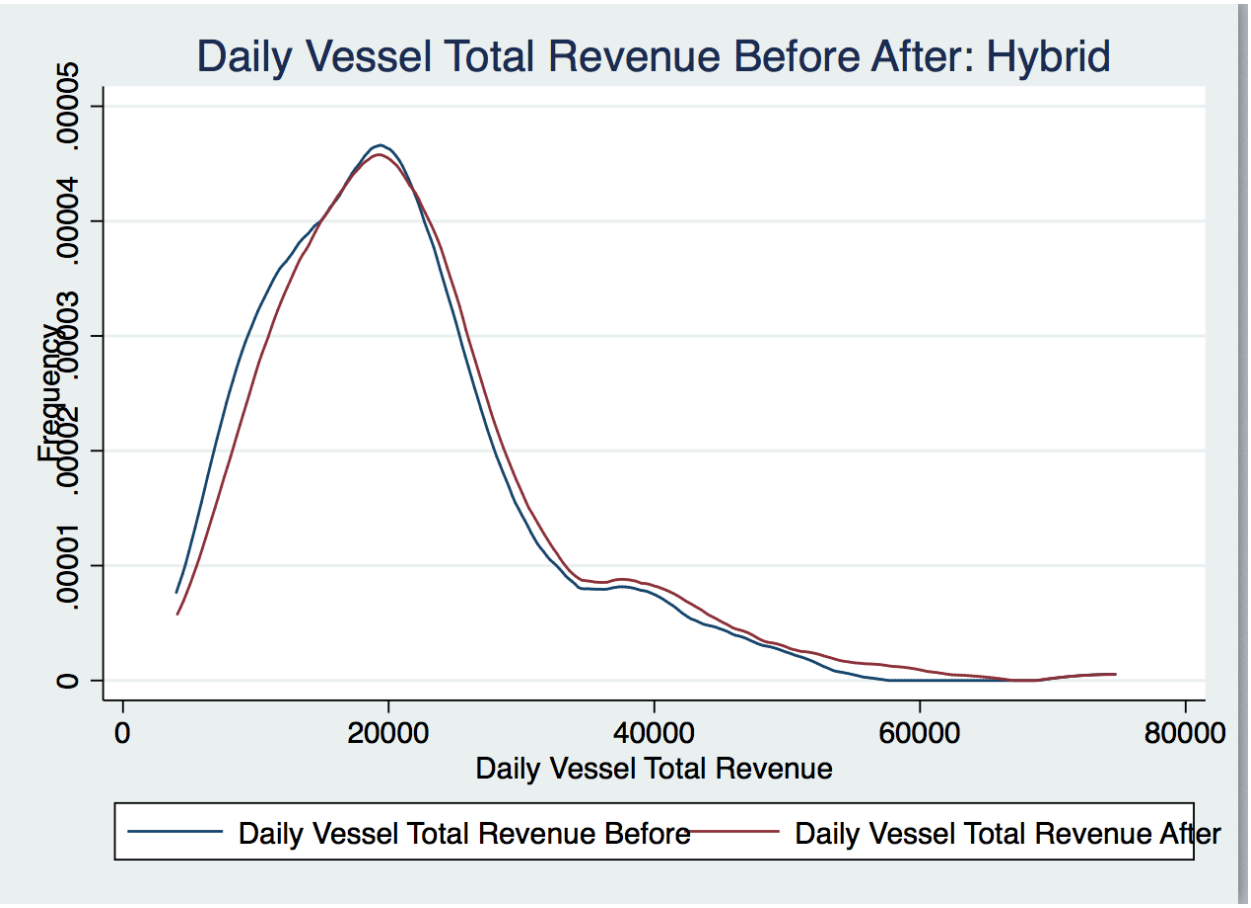
Figure 29B. Proportional Gain in Daily Vessel Revenue All States: *Days/m^3 Capacity*



Note: Vessel's days > 99. The results exclude gains in profit from reorganization within multi-vessel companies.

Figure 30A depicts daily vessel total revenue before and after the Scheme for *Hybrid*. It shows that this revenue tends increases due to the Scheme since the left-hand tail of the "before" exceeds the left-hand-tail of the "after" (because is more frequent before for these smaller values) and the right-hand tail of the "after" exceeds the right-hand tail of the "before" (since there are now more vessels with higher total revenues following the Scheme).

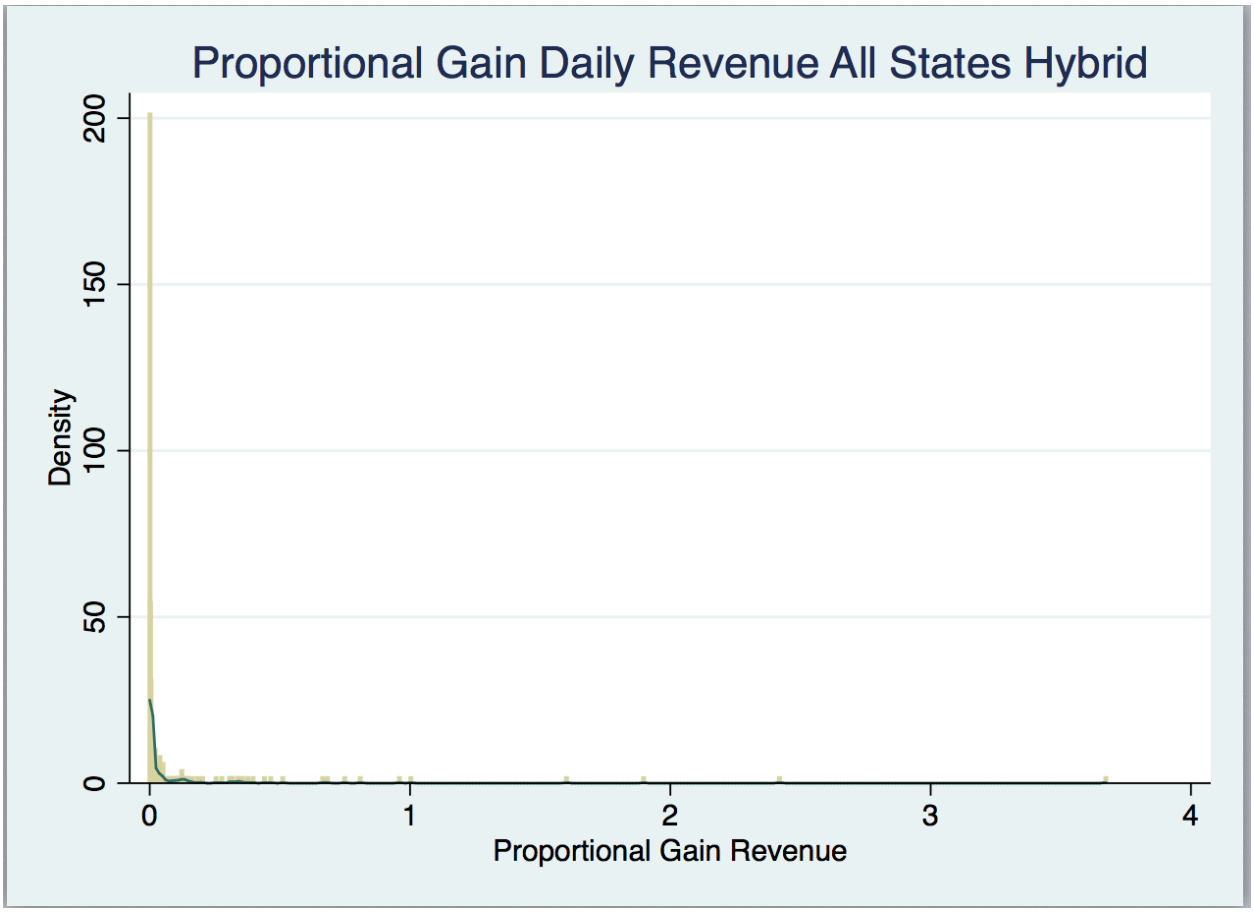
Figure 30A Daily Vessel Total Revenue Before and After Scheme: *Hybrid*



Note: Vessel's days > 99. The results exclude gains in profit from reorganization within multi-vessel companies.

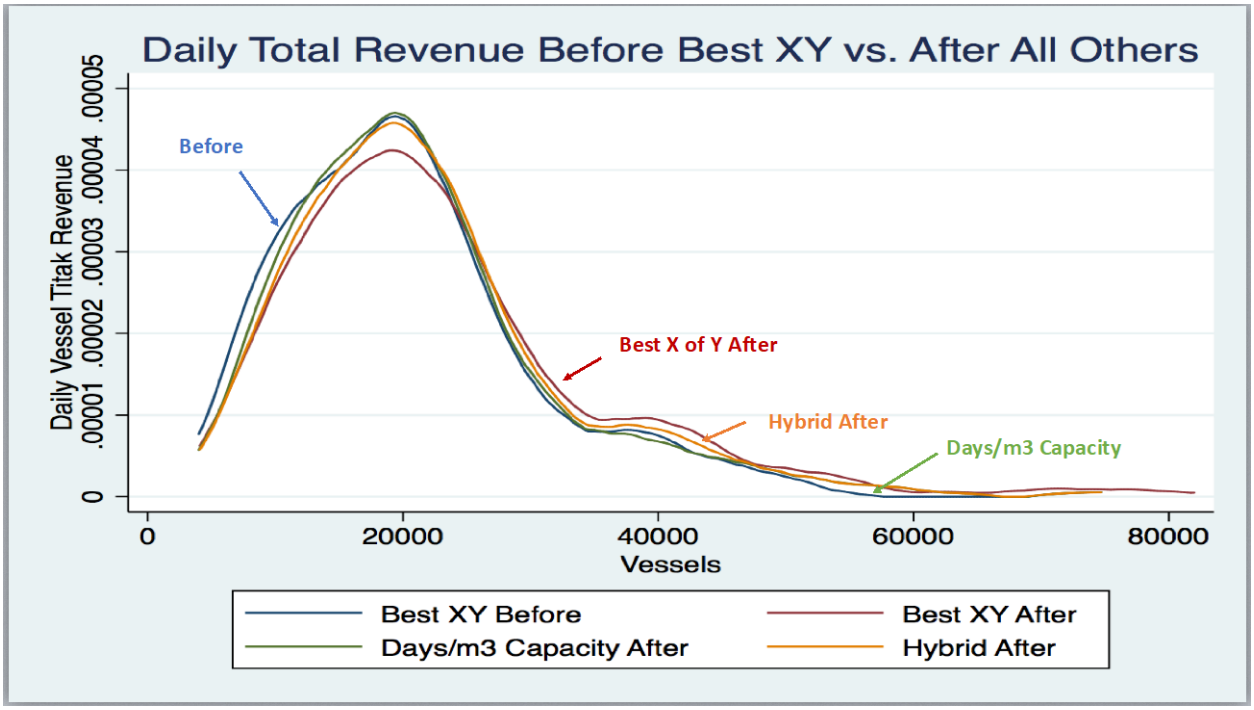
The following Figure 30B depicts the proportional gain in daily vessel total revenue for *Average 3 Years* due to the *Htybrid* PAES allocation and transferable day credit scheme (for vessels with at least 99 days). These results show that daily vessel total revenue increases, some with proportionately large increase, as indicated by the long right-hand tail. Most vessels are bunched together with moderate increases in daily vessel total revenue. No vessel is made worse off due to the Scheme.

Figure 30B. Proportional Gain in Daily Vessel Revenue All States: *Hybrid*



Note: Vessel's days > 99. The results exclude gains in profit from reorganization within multi-vessel companies.

Figure 31. Daily Vessel Total Revenue Before and After Scheme: Before versus After for *Best X of Y, Days/m3 Capacity*, and *Hybrid*.



Note: Vessel's days > 99. The results exclude gains in profit from reorganization within multi-vessel companies.

Table 8 and Figure 32 show the mean daily vessel total revenue before and after the Transferable Day Credit Scheme for *Best X of Y* and *Average 3 Years* by CPC.

Table 8. Mean Daily Vessel Total Revenue Before and After Transferable Day Credit Scheme: *Best X of Y* and *Average 3 Days by CPC*

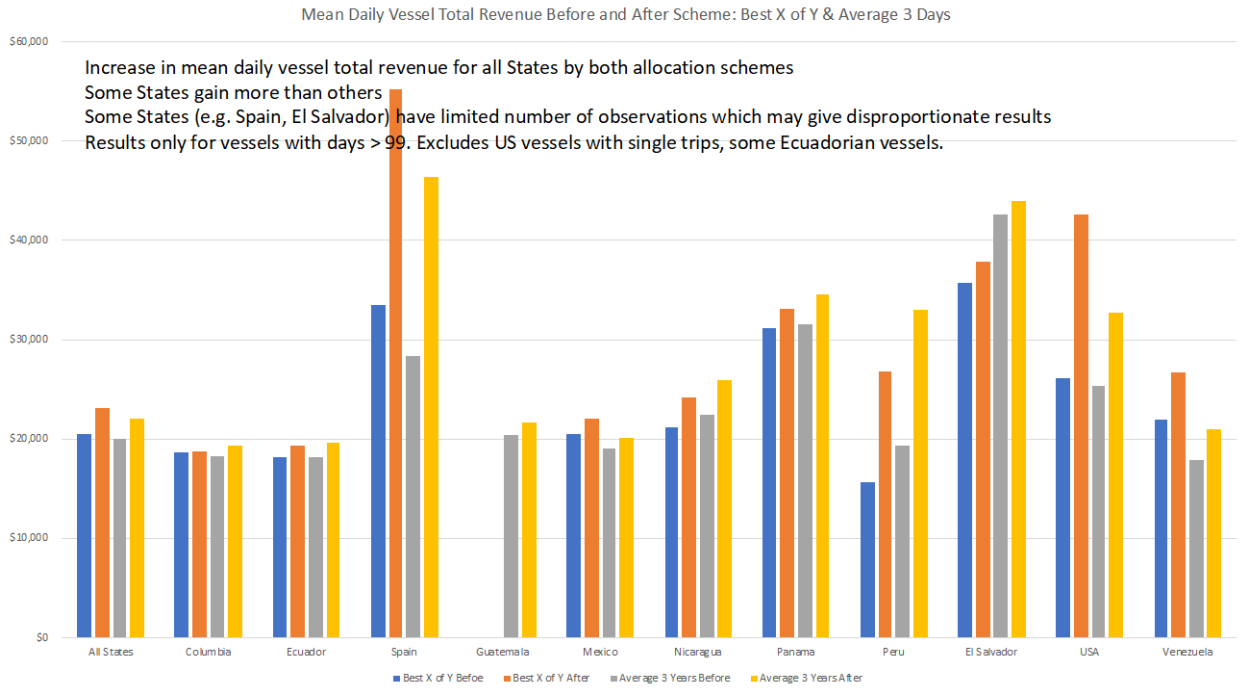
Mean Daily Vessel Total Revenue Before-and-After Transferable Day Credit Scheme: Best X of Y and Average 3 Years

State	Mean Vessel Total Revenue per Day Before Best X of Y	Mean Vessel Total Revenue per Day Before Avg 3 Years	Mean Vessel Total Revenue per Day After Best X of Y	Mean Vessel Total Revenue per Day After Avg 3 Years	Mean Annual Total Revenue per Vessel & Gain Best X of Y	Mean Annual Total Revenue per Vessel % Gain Avg 3 Years
All States	$20,534	$19,933	$23,058	$22,033	14.58%	11.02%
Columbia	$18,608	$18,211	$18,719	$19,236	1.10%	6.23%
Ecuador	$18,081	$18,111	$19,308	$19,571	9.08%	9.04%
Spain	$33,531	$28,346	$55,101	$46,329	58.38%	55.93%
Guatemala	Too few observations	$20,378	Too few observations	$21,623	Too few observations	Too few observations
Mexico	20,525	$19,059	$22,041	$20,125	11.67%	6.63%
Nicaragua	$21,188	$22,507	$24,213	$25,904	16.09%	17.38%
Panama	$31,179	$31,535	$33,052	$34,532	4.32%	11.37%
Peru	$15,656	$19,249	$26,749	$32,910	122.19%	73.70%
El Salvador	$35,750	$42,547	$37,780	$43,967	7.28%	3.04%
USA	$26,176	$25,284	$42,511	$32,750	62.57%	30.79%
Venezuela	$21,874	$17,919	$26,671	$21,053	24.34%	18.61%

Note excludes vessels with < 99 days (including USA single trips). Manta prices averaged over 2016-2018. US$2019. Some States have very limited number of

Note: Vessel's days > 99. The results exclude gains in profit from reorganization within multi-vessel companies.

Figure 32. Mean Daily Vessel Total Revenue Before and After Transferable Day Credit Scheme: *Best X of Y* and *Average 3 Days by CPC*

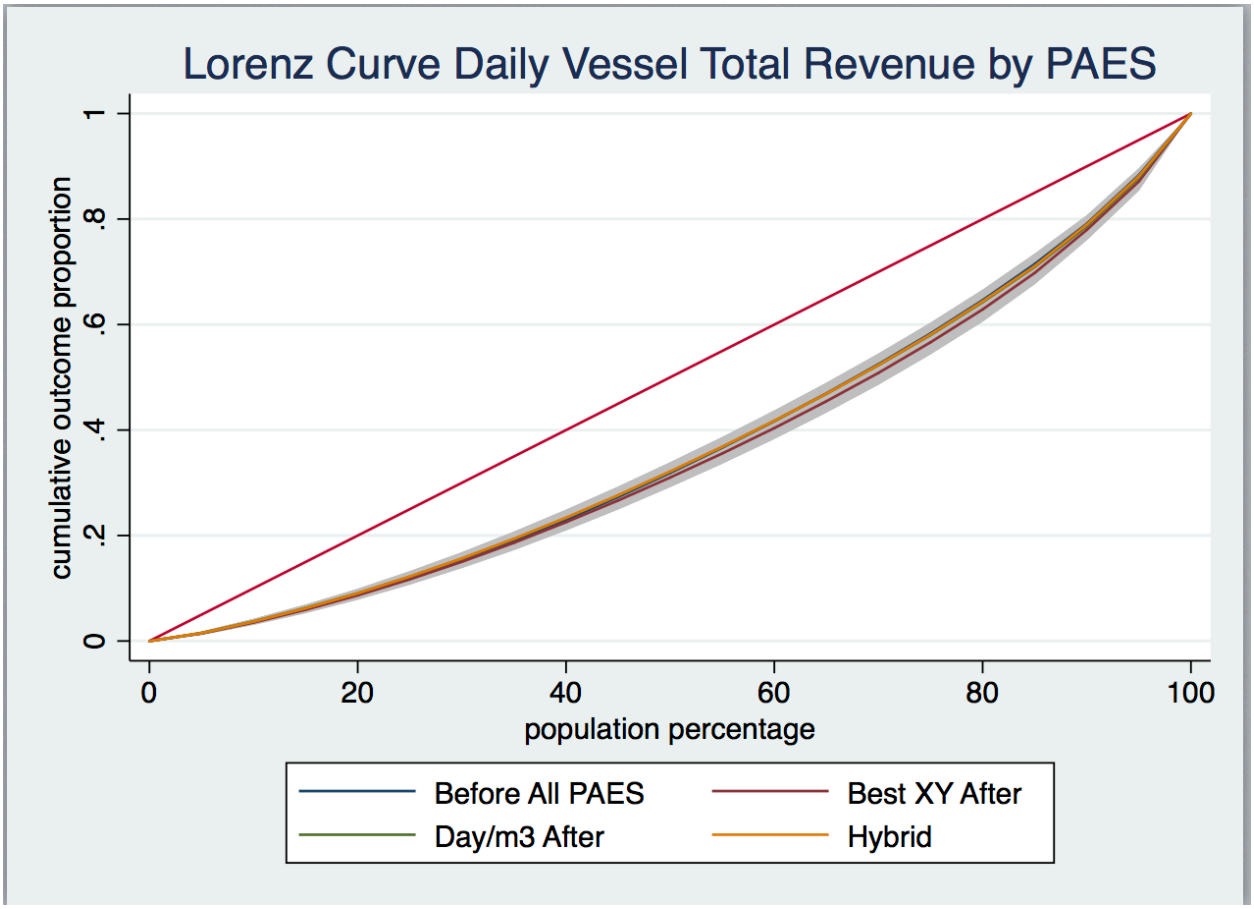


8.2. Equity of Daily Vessel Total Revenue by PAES Allocation Type

Conclusions on Equity of Daily Vessel Total Revenue by PAES Allocation Type

- Daily vessel total revenue is distributed with greater equity among vessels than is daily vessel operating profit (as indicated by the value of equity metrics)
- Ranked in terms of most equity to least equity:
    - *Hybrid > Days/m3 Capacity > Best X of Y > Average 3 Years*

Figure 33. Lorenz Curve of Daily Vessel Total Revenue by PAES Allocation Type



Note: Vessel's days > 99.

Table 9 summarizes the mean daily vessel total revenue, the Atkinson inequality (equity) measure, and their relative ranks. The mean revenues are all close in value and are ranked from highest to lowest

Table 9. Summary of Economic Efficiency and Equity by PAES Allocation Type

Type of PAES Allocation	Mean Daily Vessel Total Revenue (US$)	Rank of Daily Total Revenue Highest to Lowest	Atkinson's Inequality Measure (γ=1)	Rank of Equality Highest to Lowest
Average 3 Years	22,003	2	0.13112	4
Best X of Y	23,058	1	0.12290	3
Days/m^3 Capacity	21,424	4	0.10994	2
Hybrid	21,954	3	0.10918	1

Note: Vessel's days > 99. Including vessels with days < 99 gave nonsensical empirical results. The results exclude gains in total revenue from reorganization within multi-vessel companies.

Average 3 Years is calculated from different data than the other three PAES formulae
Atkinson: Lower values more equal, $0 \leq A(\gamma = 1) \leq 1$. Atkinson can be interpreted as the percentage of per capita "income" (here daily vessel operating profit per vessel) that would provide the same total welfare as the actual "income" if it were equally distributed.

The following Figure 34 depicts the equity-efficiency trade-off after the Scheme for daily vessel total revenue and depicts Table 9. The higher on the figure the more efficient in terms of daily vessel total revenue and the more to the right-hand side the greater the equality of distribution of daily vessel total revenue among vessels.

Figure 34. Equity-Efficiency Trade-Off Among Vessels: Daily Vessel Total Revenue