Supplementary Information

From publication to action: Connecting science, policy, and public attention for ocean-related climate mitigation

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1 LLM classifer of ORO type

Supplementary Table 1: Eligibility criteria for article inclusion. Articles are screened for inclusion/exclusion based on the title, abstract and keywords. If any criterion fails the article is excluded – all criteria must be met in order to be included. If insufficient information is provided to cause sufficient doubt that a criterion is met, assume the criterion is failed.

	INCLUDE	EXCLUDE
Article language	Article is written in English	Article is not written in English
Population	The intervention located in a marine system (open-ocean, coastal ocean, coastal land). This includes: coastal and intertidal/brackish habitats (e.g. estuaries, saline coastal wetlands, tidal marshes, mangroves); pelagic & benthic zones across all biomes; seas, gulfs, and oceans; artificial habitats	The intervention is located on coastal land and not associated with coastal blue carbon habitats or ocean-related resources; e.g. terrestrial and freshwater ecosystems (e.g. rivers, freshwater wetlands)

Intervention	The intervention/exposure being studied is: **A.** A mitigation ORO* (at any development stage including design, implemented and future upscaling); or **B.** Where no explicit intervention is present, the following study types will be included as relevant for the 'design' stage : **i)** exposure to natural analogues of a proposed mitigation ORO such as a natural sargassum bloom as an analogue for macroalgae cultivation; **ii)** observations of natural carbon flux/storage in blue carbon ecosystems; **iii)** studies relevant for estimating the potential of a proposed ORO, e.g. "Effectiveness of CO2 sequestration in the pre- and post-industrial oceans"; **iv)** theoretical idea/concept/technology for an ORO is being developed; **(v)** preliminary testing of the concept is being carried out ex-situ or in-situ (i.e. pilot study); **vi** assessing potential side effects from the proposed ORO (note we exclude speculative opinons/extrapolating concluding statements).	No intervention is studied. This includes: hypothetical/relevance statements to a mitigation ORO in the introduction/conclusion but the ORO is not the main subject of the paper; technological advancements without explicit implementation/application to an ORO; advancements in modelling capacity/predictability that are not related to upscaling/future siting (e.g. improving forecasting models which has future applications for improving the resilience of marine renewable energy infrastructure to extreme weather); the intervention relates to solar radiation or heat management; neutral interventions (e.g. cultivation of algae for food and feed); actions mitigating pollutants that are not greenhouse gases (e.g. nitrogen oxide and sulphur oxide emissions); studies indirectly relevant to an intervention (except blue carbon) where no explicit link to the intervention is made (e.g. exclude articles discussing the natural processes driving carbon export in the open ocean - if there is no explicit mention of ocean iron fertilisation)
Study design	The study is a primary research article. This includes: book chapters (where primary research is indicated), conference proceedings, engineering papers presenting technological developments, empirical research (e.g. experimental and observational), modelling studies of upscaling potential/future siting, cost analyses, social science primary methodologies such as opinion surveys (contrary to excluding articles presenting author opinions/perspectives, opinion can be included as eligible data if recorded via a structured social science protocol like a survey).	The following study types are excluded: author opinions/perspectives (e.g. Ricart et al 2022 https://doi.org/10.1088/1748-9326/ac82ff); reviews and meta-analyses; book introduction chapters; introductions to conference proceedings

* Definition of mitigation ORO: A human action (or control thereof, e.g. conservation interventions can be the limiting of human actions/stressors) with uses ocean-related resources to mitigate atmospheric greenhouse gases (e.g. marine renewable energies, reducing emissions in marine industries, increasing carbon sequestration, providing a location for storage of captured carbon, or addressing climate change). This includes hybrid options partly based on land, as well as actions to protect, rehabilitate or enhance blue carbon habitats. For interventions where several objectives are possible (e.g. restoring a mangrove ecosystem), mitigation objectives (can be stated in terms of desired outcomes such as increasing carbon sequestration) must be clearly stated.

Supplementary Table 2: Mitigation ORO type definitions, and the number of articles coded as relevant for each type in the LLM training data set.

ORO type	Definition	N
MRE-Ocean	Marine renewable energy technologies that convert ocean energy (e.g. tide, wave)	349
MRE-Located	Marine renewable energy technologies that are located in the ocean, but are not inherently ocean-obligate – i.e. they convert energy from other sources that are not oceanic (e.g. floating solar panels, offshore wind farms)	343
MRE-Bio	Energy is converted from marine biological sources, e.g. macroalgae cultivation	110
Incr. Efficiency	Options to increase energetic efficiency that result in emissions avoided.	158
CCS	Options that store captured carbon (e.g. from direct air capture) in ocean resevoirs (e.g. deep waters or sediments).	256
CDR-Blue Carbon	Options that aim to increase the carbon sequestration of natural carbon sinks in blue carbon ecosystems through conservation, restoration, or afforestation. \	195
CDR-OAE	Options that aim to increase the carbon sequestration potential of the ocean via the addition of alkaline materials.	172
CDR-Biol. C. Pump	Options to enhance the biological carbon pump (e.g ocean iron fertilization, artificial upwelling)	160
CDR-Cultivation	Options where mariculture of macro or micro-algae is used to sequester carbon dioxide by sinking the cultivated biomass.	53
CDR-Other	Other options that aim to increase ocean-related carbon sequestration that do not fall into the previous CDR categories. For example, sinking of terrestrial biomass in the ocean	22

Supplementary Table 3: Per-label performance metrics for the multi-label classification model for ORO type. The hyper-parameters for: batch size, weight decay, learning rate, number of epochs, and class weight (-1 indicates no weighting applied) for the best-performing model configuration are also listed.

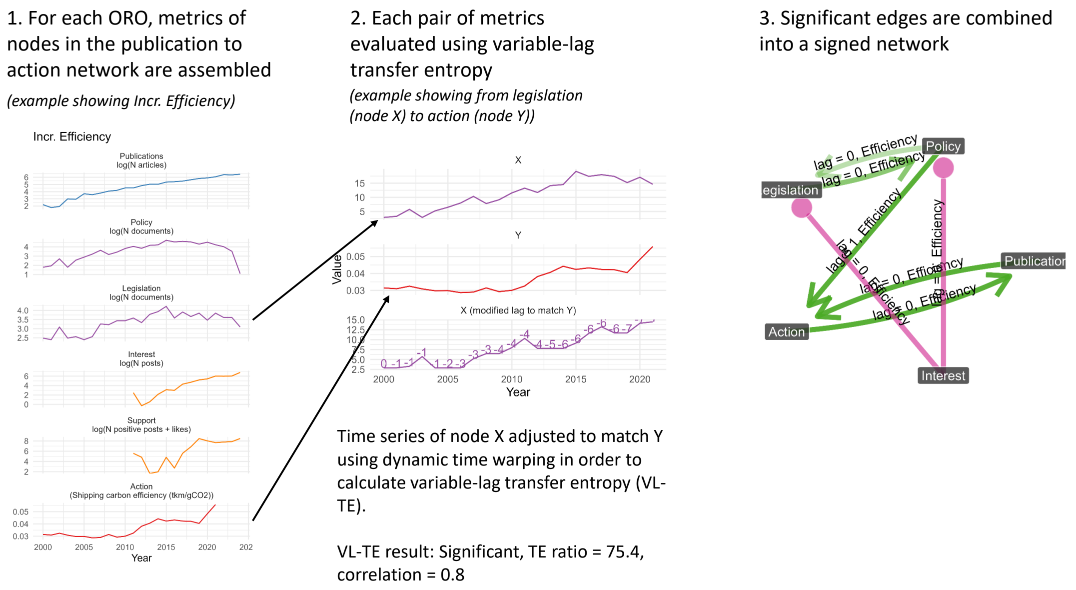
ORO type	F1 - label	ROC AUC - label	precision - label	recall - label	accuracy - label	batch size	weight decay	learning rate	N epochs	class weight
MRE-Ocean	0.77	0.93	0.75	0.80	0.90	16	0	5.00E-05	4	-1
MRE-Located	0.77	0.93	0.69	0.89	0.88	16	0	5.00E-05	4	-1
CCS	0.72	0.94	0.71	0.73	0.95	16	0	5.00E-05	4	-1
CDR-Blue Carbon	0.84	0.97	0.89	0.80	0.96	16	0	5.00E-05	4	-1
MRE-Bio	0.78	0.98	0.76	0.81	0.98	16	0	5.00E-05	4	-1
Incr. efficiency	0.80	0.94	0.80	0.80	0.96	16	0	5.00E-05	4	-1
CDR-OAE	0.71	0.95	0.75	0.71	0.97	16	0	5.00E-05	4	-1
CDR-Biol. C. Pump	0.70	0.93	0.75	0.68	0.97	32	0	5.00E-05	4	-1

2 FAOLEX and ECOLEX searches

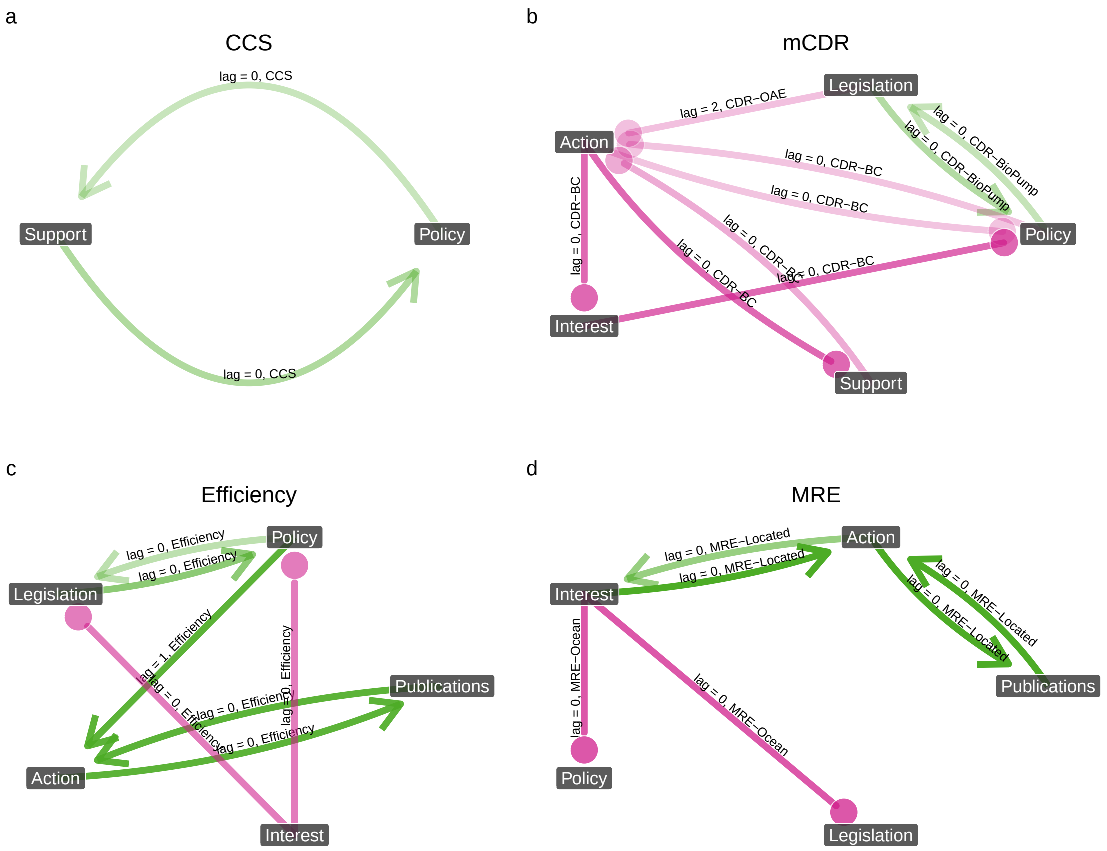
Supplementary Table 4: Search queries used to identify documents relevant to each ORO type from texts indexed in Whoosh [1]

ORO type	Whoosh query
MRE-Located	“offshore wind” OR “offshore solar*”$\sim$2 OR “offshore photovoltaic”$\sim$3
MRE-Ocean	(wave OR tidal OR tide OR “ocean current”$\sim$5 OR thermohaline OR OTEC OR “salinity gradient$” OR “ocean geotherm*”) AND (energy OR power OR turbine$)
MRE-Bio	(seaweed OR “sea weed” OR macroalgae OR microalgae OR phytoplankton) (biofuel OR fuel) NOT (pollut* OR hygen*)
Incr. efficiency	(marine OR ocean OR sea$ OR offshore OR ship OR ship* OR “international maritime organi?ation”) AND (((clean OR alternat*) AND (fuel$ OR diesel) OR biofuel$ OR efficien* OR technol*) AND (((carbon emission$) OR “climate change”)’
CCS	(marine OR ocean* OR sea$ OR deep-sea) AND “carbon stor*”$\sim$10)
CDR-Blue Carbon	“blue carbon” OR ((carbon OR “climate change” OR emission*) AND (mangrov* OR wetland$ OR “salt marsh*” OR seaweed OR “sea weed” OR macroalgae OR seagrass))
CDR-OAE	“(marine OR ocean OR sea$) (alkalin* OR olivine OR silicate OR liming OR lime* OR weathering)”$\sim$10
CDR-Biol. C. Pump	“iron (fertili?ation OR enhanc* OR enrich*)”$\sim$3 OR “(artificial OR enhanc* OR increas*) upwell*”$\sim$5 OR ((increas* OR enhanc*) AND (“biological pump”$\sim$3 OR “primary production”))’

3 Network analysis



Supplementary Figure 1: Graphical description of the method using variable-lag transfer entropy [2] to construct signed networks informed by compiled metrics. This example shows the *Incr. efficiency* ORO type, but analogous analyses were conducted for all ORO types.



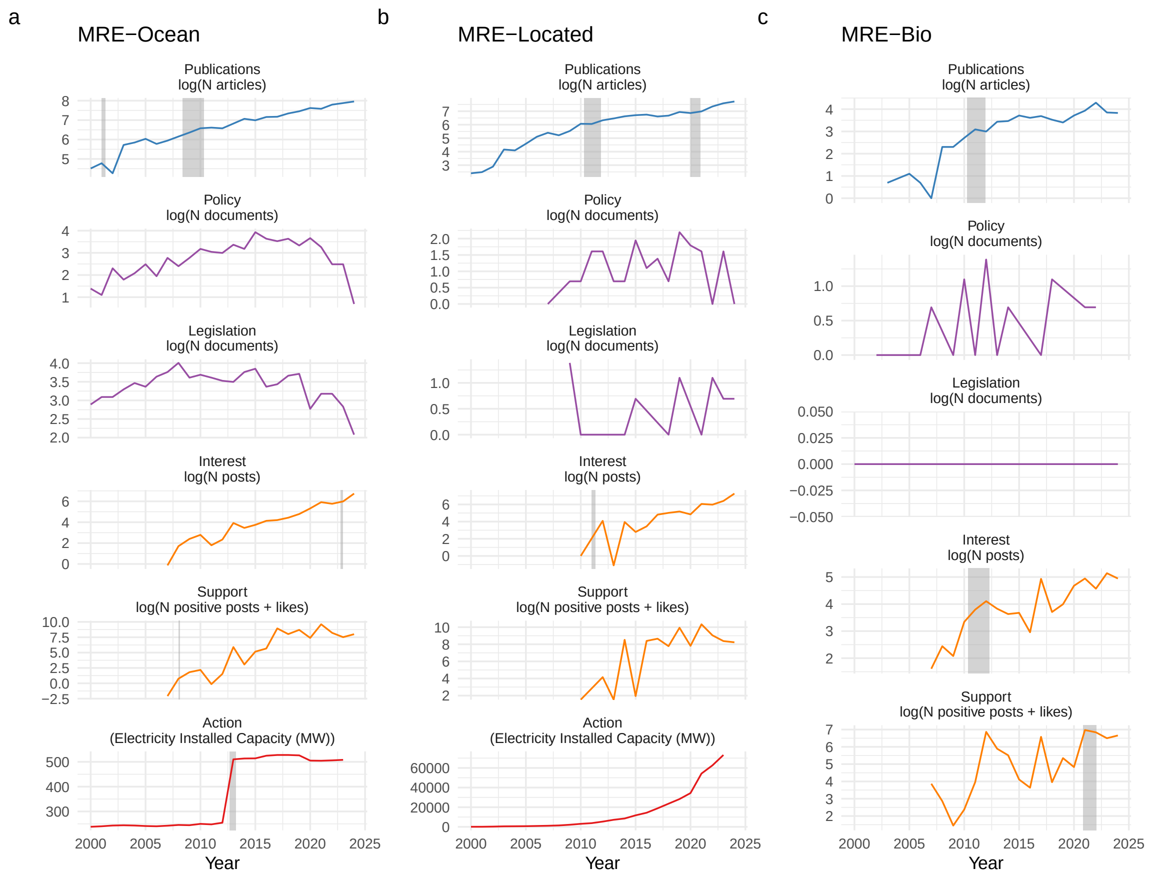
Supplementary Figure 2: Networks of causal relationships detected for groupings of similar OROs. Each signed network digraphs shows the significant edges between nodes detected from variable-lag transfer entropy. Each node is represented by a circle. Edges showing the flow of effect between the nodes are represented as green arrows for a positive effect and pink dots for a negative effect (determined by the sign of the optimal correlation between the two time series). The transparency of each edge is proportional to the average transfer entropy ratio, where higher values indicate greater strength of changes in node X causing changes in node Y [2]. The saturation of the edge colour indicates the number of OROs in which the edge was found. The ORO(s) for which each edge is detected, and the optimal lag which produced the highest correlation are written along the length of each edge line.

4 GLM analysis

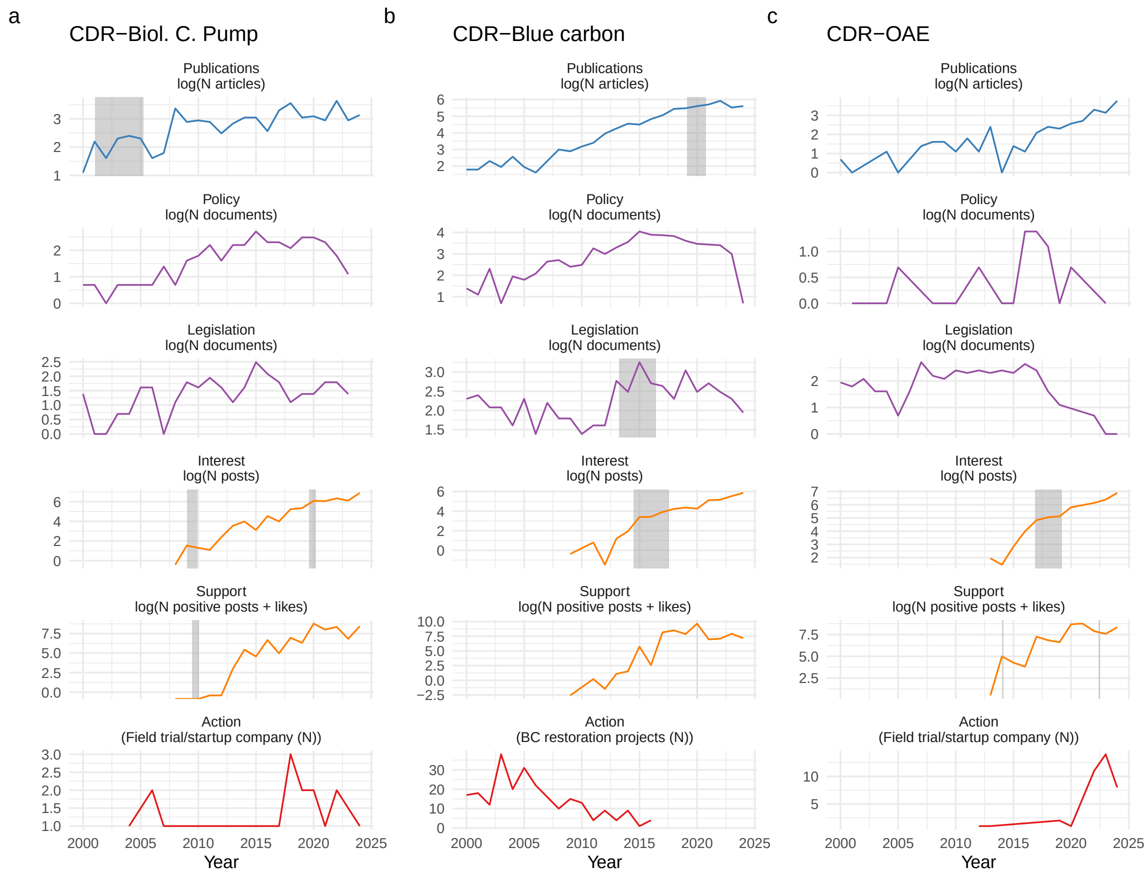
Supplementary Table 5: Coefficients for the generalised linear regression of each node with respect to the proportion of publications.

Node	Coefficient	Estimate	Std. Error	t value	P-value	Distribution
Policy	(Intercept)	1.30E+00	3.70E+01	3.60E-02	9.70E-01	Quasibinomial (dispersion = 21)
Policy	Proportion of publications	9.40E-01	5.10E-01	1.80E+00	6.80E-02	Quasibinomial (dispersion = 21)
Policy	Year	-1.70E-03	1.80E-02	-9.20E-02	9.30E-01	Quasibinomial (dispersion = 21)
Legislation	(Intercept)	-4.60E+00	2.70E+01	-1.70E-01	8.60E-01	Quasibinomial (dispersion = 13)
Legislation	Proportion of publications	3.00E+00	3.90E-01	7.60E+00	1.10E-12	Quasibinomial (dispersion = 13)
Legislation	Year	1.10E-03	1.30E-02	8.20E-02	9.30E-01	Quasibinomial (dispersion = 13)
Interest	(Intercept)	-1.80E+00	3.20E+01	-5.80E-02	9.50E-01	Quasibinomial (dispersion = 38)
Interest	Proportion of publications	4.30E-01	2.60E-01	1.60E+00	1.00E-01	Quasibinomial (dispersion = 38)
Interest	Year	-7.80E-05	1.60E-02	-4.90E-03	1.00E+00	Quasibinomial (dispersion = 38)
Support	(Intercept)	-2.60E+00	8.80E+01	-3.00E-02	9.80E-01	Quasibinomial (dispersion = 2,570)
Support	Proportion of publications	1.90E+00	5.30E-01	3.50E+00	5.90E-04	Quasibinomial (dispersion = 2,570)
Support	Year	2.10E-04	4.40E-02	4.80E-03	1.00E+00	Quasibinomial (dispersion = 2,570)

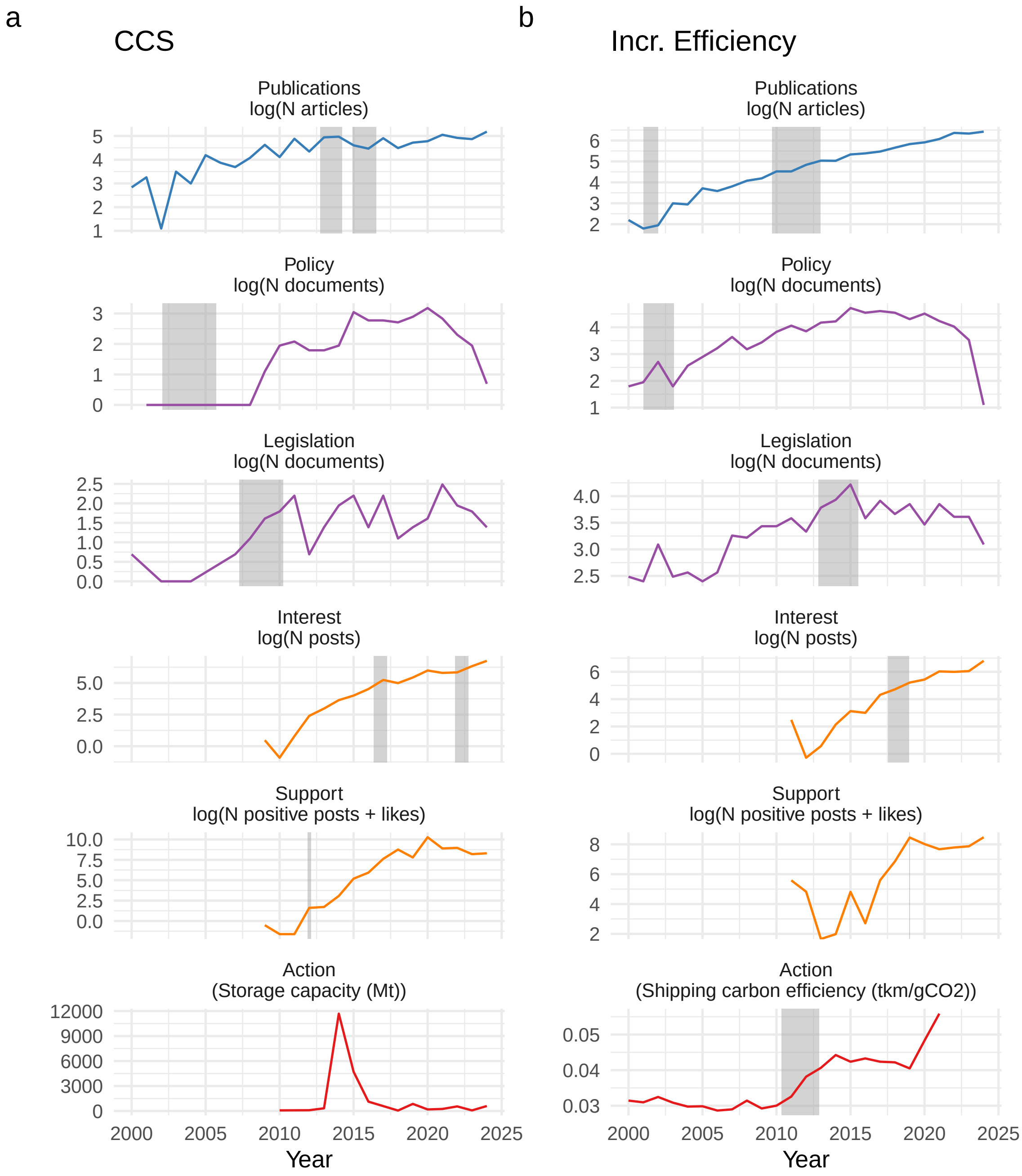
5 Narrative analysis



Supplementary Figure 3: Inflection points in the 'MRE' publication to action metrics. Panels **a-c** show each time series for the publication to action network for the ORO types in the 'MRE' group. Grey shaded envelopes indicate years where an inflection point was detected by a Bayesian change point analysis (25% to 75% prediction intervals).



Supplementary Figure 4: Inflection points in the 'mCDR' publication to action metrics. Panels **a-c** show each time series for the publication to action network for the ORO types in the 'mCDR' group. Grey shaded envelopes indicate years where an inflection point was detected by a Bayesian change point analysis (25% to 75% prediction intervals).



Supplementary Figure 5: Inflection points for CCS and 'Efficiency' publication to action metrics. Panels **a&b** show each time series for the publication to action network for the *CCS* and *Incr. Efficiency* ORO types. Grey shaded envelopes indicate years where an inflection point was detected by a Bayesian change point analysis (25% to 75% prediction intervals).

References

1. Chaput, M. *Whoosh: Pure-Python full-text indexing and searching library* 2024.
2. Amornbunchornvej, C., Zheleva, E. & Berger-Wolf, T. Variable-lag granger causality and transfer entropy for time series analysis. *ACM Transactions on Knowledge Discovery from Data (TKDD)* **15.** Publisher: ACM New York, NY, USA, 1–30 (2021).