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A synopsis of economic and management performance of the Senegalese deep-water pink shrimp (*Parapenaeus longirostris*) fishery

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Abstract
Economics of the pink shrimp (*Parapenaeus longirostris*) fishery in Senegal is not only affected by shrimp abundance and markets but also fisheries management and policy. The introduction of the quotas system in 2015 has allowed the firms to increase their catch values. This fishery helps and promotes the sustainable development of the industry, but only slightly benefited the Senegalese government because it provided less contribution to employment an estimated 852 people and US$4.583 million per year of the Gross Domestic Product according to the added value. This paper summarizes the economic outcome of management measures for the deep-water shrimp fishery under Senegalese jurisdiction. Threats such as species slightly overexploited caused by fishing effort and false fishing are identified and management measures such as scientific collection and monitoring of fishery information, catch limits, breeding zones and demonstrating the need for increased involvement of fishers in the management decision-making process are suggested.

Keywords: *Parapenaeus longirostris*, economic, fisheries management and policy, Senegalese, employment

1. Introduction
The government of Senegal regards fishing as a particularly important sector of the economy because it provides food security, employment, and export income [1]. Fisheries in Senegal have been identified as a potential driver of growth in the nations plan for economic development termed the Emerging Senegal Plan (ESP). This economic focus carries the risk of over-investment and over-exploitation unless well supported by management and research including economic analyses.

1.1 Resource management
Management of *P. longirostris* is conducted by the Senegalese Cooperative Exploitation of the Deep-water Shrimp Fisheries (Coopérative Sénégalaise d'Exploitation de la Pêcherie de Crevette Profonde - COSECPRO). Individual transferable quotas (ITQs) have been implemented with the objective of improving economic performance with some signs of improvement to date. This introduction of the quotas allowed the firms to increase their catch values and to obtain the high value of their landings. However, the distribution was determined on the basis of the historical catches of each member of the COSECPRO. These ITQs are normally viewed as an economic tool. Furthermore, the management plan implemented has goals to maximize the rent generated through the rational use of the deep-water shrimp resource and then respecting the ecological and social imperatives determined by the government of Senegal [2].

1.2 Legal background in Senegal
If the total catch exceeds the Total Allowable Catch (TAC), which stays around 2,500 tonnes per year for deep-water pink shrimp, COSECPRO must pay a penalty to Senegal's Public Treasury on each kilogram of shrimp over the limit. The amount of this penalty is set annually by the Minister of Economy and Finance and the Minister of Fisheries and Maritime Economy. If the TAC of year n is exceeded, the TAC for the year n + 1 is reduced by the excess of unauthorized catches made in year n.

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Therefore, COSECPRO members are subject to the laws and regulations that govern the granting, renewal, and conditions of validity and use of fishing licenses [2]. However, ITQs have helped the profitability of firms but have reduced the benefit from the fishery to the national economy because they provide less employment and the profits flow to a small number of private firms. Thus, deep-water shrimp trawlers must possess a valid fishing license and are subject to the Annual Authorized Catch (AAC). Before the beginning of each fishing campaign, COSECPRO informs its members of their respective AAC once the TAC has been set. Each member divides their AAC between their different vessels authorized to fish, taking into account the catching capacity of each vessel. Additionally, the Fisheries Management Organization (FMO) was formed, and its members propose to the Minister of Fisheries and Maritime Economy (MFME) the legal form of the FMO.

2. Methods
2.1 Fishery data
The data used in this study are the total catch of deep-water pink shrimp per year of industrial fishing operating in the Senegalese exclusive economic zones (EEZs) and were collected from government records, the Centre for Oceanographic Research (Centre de Recherches Océanographiques de Dakar-Thiaroye_CRODT) and Maritime Fisheries Department (Direction des Pêches Maritimes – DPM) database. The catch data before 2016 likely mixed two very different species of shrimp: *Aristeus varidens* and *Parapenaeus longirostris*. Therefore, this study focuses on the years 2016, 2017, and 2018 instead of utilizing uncertain data. In Senegal, fishing must occur in the zones (e.g. northern, central zone, southern zone, and common zone illustrated in Figure 1) determined according to the Fisheries Act of Law 98–32 of 1998. It should be noted that 100% of the landings of *P. longirostris* are done at the Dakar Autonomous Port showed in Figure 1.

Fig 1: Different zones (DZs) of the deep-water shrimp trawler fishery activities in Senegalese exclusive economic zone and common zone.

The economic data available included yearly data on the import and export, taxes, profit, the gross value of production, turnover, prices, variable and fixed costs. This economic data was collected by the members of COSECPRO and some researchers at the CRODT in April 2018. It was also provided by them. Moreover, it was converted on West African CFA Franc to US Dollar (exchange rate 1US = 623.723 CFA Francs on 31/12/2016; 1US = 551.771 CFA Francs on 1/12/2017; and 1US = 579.782 CFA Franc on 01/12/2018). However, the prices of the *P. longirostris* were adjusted for inflation. As for the royalty fees, it can be calculated as follows:

- Public treasury $= \frac{\text{Current payment} * 95}{100} * \frac{1}{2}$

- Fund for the encouragement of Fishing and its Related Industries $= \frac{\text{Current payment} * 95}{100} * \frac{2}{3}$

- Cooperation Management Agency $= \frac{\text{Current payment} * 5}{100}$

2.2 Trends in catch
From 2016 to 2017, the total catch increased from 1,401 to 2679 tonnes. It later decreased to 1,663 tonnes in 2018 shown in Figure 2. Therefore, the fishing strategy was conditioned by changes in catchability of *P. longirostris* [3].
Using an April 2018 data from the CRODT, our stock assessment shows that the biomass of *P. longirostris* was slightly overexploited due to a decrease in fishing potential (Maximum Sustainable Yield global) from 2016 to 2017 (2,664 to 2,415 tonnes), but then increased slightly to 2,443 tonnes shown in Figure 2 in 2018. As it relates to the figure below, the deep-water shrimp trawl fishery caught approximately 81% of the *P. longirostris* population.
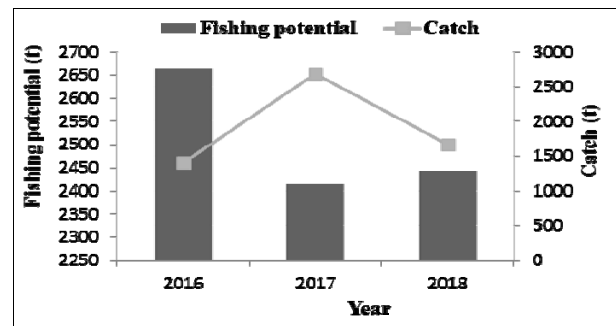
Fig 2: Trends in fishing potential (t) and catches (t) of deep-water pink shrimp in the waters of Senegal from 2016 to 2018.

3. Results
### 3.1 Macroeconomic importance of that specific fleet for Senegal
3.1.1 Import and export
The effect of the fishery on export income to the country as reduced by imported inputs such as fishing equipment (US$ 782,340), packaging ($ 1.151 million US), and import of the vessel ($ 1.024 million US). Export values of deep-water pink shrimp increased from $ 9.270 million US in 2016 to $ 14.499 million US in 2017, while the estimated gross revenue showed a decrease from $13.211; $11.231; and $ 9.350 million US between 2016; 2017; and 2018 respectively.

3.1.2 Taxes
Taxes are paid in terms of royalty fees. The royalty rates are established by the public treasury, the Caisse d'encouragement de la Pêche et de ses Industries Annexes

(Fund for the encouragement of Fishing and its Related Industries - FFRI), and the Cooperation Management Agency (CMA), taking into account the gross registered tonnage (GRT) during the period 2006–2015 showed in Figure 3. The royalty rates paid to the FFRI, public treasury, and CMA were high in 2006 and 2011 due to the gross registered tonnage. It decreased in 2008, but saw increases in the years 2007, 2009, 2010, 2012, 2013, 2014, and 2015 illustrated in Figure 3. It is necessary to note that all three rates moved in the same direction during the period 2006–2015.
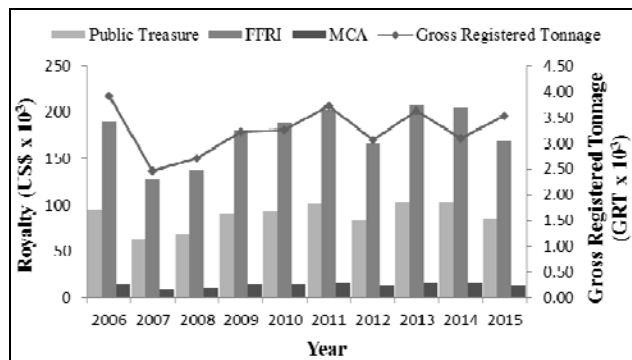
Fig 3: Evolution of royalty (US$ x 10³) generated of the deep-water shrimp trawlers in the Public Treasure, Fund for the encouragement of Fishing and its Related Industries (FFRI) and Cooperation Management Agency (CMA) taking into account of the gross registered tonnage (GRT x 10³) from 2006 to 2015.

3.1.3 Contribution to the Gross Domestic Product
The Gross Domestic Product (GDP) is the market value of all officially recognized final goods and services produced within a country during a given period [4]. A common way to estimate GDP is the "production approach" through the calculation of the Added Value (AV) where
GDP = AV + Taxes – Subsidies.
However, data on taxes and subsidies were not available specifically for deep-water pink shrimp fisheries. Therefore, this study considers the AV to be the sole contributor to GDP for the deep-water shrimp fisheries sector.
The deep-water shrimp fisheries sector only slightly benefited the Senegalese government. It also provided a weak contribution to the national GDP according to the Added Value (AV), which was around US$4.583 million per year. Thus, a significant part of the total generated AV, namely 50%, went outside the country. There was also a very low contribution of US$84,817 to the public treasury in 2015 due to low, inefficient taxation of the fleets, which benefited from their status under the Free Trade Companies. The contributions made were from fishing licenses and were approximately US$618,628 in 2017 for *P. longirostris* alone.

3.1.4 Employment
Senegal's deep-water shrimp fleet is composed of 6 fleets, of which 4 (with names such as fleet_G, fleet_H, SA, fleet_H, and fleet_OP, SA) are currently operational. These 4 fleets are composed of 16 vessels. There are typically around 352 fishermen for all 16 vessels, of which 22 fishermen per crew. Therefore, it should be noted that some large fleets of the fishery are directly employed and paid per land 500 people.

3.1.5 Markets for the landings
The landing price was estimated at US$5,623 per ton in 2017 and US$5,641.5 per ton in 2018. Additionally, the total operating variable cost of the fleet in 2017 was US$6.34

million and US$10.893 million in 2018. The 2017 average operating fixed cost of the fleet was approximately US$1.1 million, and in 2018, it was US$2.234 million.
Deep-water pink shrimp is marketed almost exclusively to the Spanish market. In Spain, seafood consumption was around 24.87 kg per inhabitant in 2017, of which 1.2 kg were shrimp and lobsters[1]. Therefore, the weighted average price of the deep-water pink shrimp depends on its market supply and importance in the Spanish market. Despite there being a large number of shrimp species such as *Hymenopenaeus muelleri* and *Penaeus vannamei*, there are no substitutes for deep-water pink shrimp in Senegal sent to the Spanish market, as these different species come from other countries.
[1]Statista.com.
https://www.statista.com/statistics/443969/seafood-consumption-volumein-spain, Accessed date: 5-February-2019.
Upon analysis of the weighted average price (WAP) of fleet_H, SA, we find that it was highest in 2016-2017 (US$7.66) and slightly decreased to US$6.15 in 2017-2018. The WAP of fleet_G showed this same trend. However, the WAP of fleet_OP, SA was highest at US$6.5 in 2016-2017 and then increased slightly to US$6.85 in 2017-2018. The same phenomenon was observed in the WAP of fleet_H showed in Table 1.

Table 1: The weighted average price of the *Parapenaeus longirostris* of the fishery fleet in the Spanish market over the period 2016-2017 and 2017-2018.

Fleet	2016_2017 Weighted average price (US$)/kg	2017_2018 Weighted average price (US$)/kg
Fleet_G	5.02	4.05
Fleet_H, SA	7.66	6.15
Fleet_H	5.02	5.88
Fleet_OP, SA	6.5	6.85

3.1.6 Analysis of the performance of the fleet
Dynamics of deep-water pink shrimp profit: In 2017-2018, fleet_H made more profit (US$1, 498,668.8) than in 2016-2017 (US$ 654,896.1). This trend was also observed for fleet_OP, SA in 2016-2017 and 2017-2018. The profit for fleet_H, SA was high in 2016-2017, but was negative in 2017-2018. However, the profit of fleet_G was negative over both the 2016-2017 and 2017-2018 periods illustrated in Table 2.
Dynamics of deep-water pink shrimp gross value of production: The gross value of production of the overall fleet was high in 2017 at US$30,164,041.34 and even higher in 2018 at US$44,815,792. However, the gross value of production of our estimated model has a lower maximum sustainable yield but a higher maximum economic yield in 2017 than in 2018. This same trend is shown for the sustainable yield of income when taking into account biomass, which was higher in 2017 than it was in 2018 showed in Table 3.

Table 2: Profit (US$) of *Parapenaeus longirostris* fishery fleet in the waters of Senegal over the period 2016-2017 and 2017-2018.

Fleet	Profit (US$)_2016_2017	Profit (US$)_2017_2018
Fleet_G	- 415,080.7	-274,711.7
Fleet_H,SA	118,826	-1,108,139.7
Fleet_H	654,896.1	1,498,668.8
Fleet_OP,SA	135,088.6	371,296.4

Table 3: Gross value of production of the estimated model (2017-2018) corresponding to maximum economic yield, maximum sustainable yield, sustainable yield taking into account the biomass of the year (t), and the fleet of the year (t).

Parameters	Estimated model 2017 (US$)	Estimated model 2018 (US$)
Gross value of production of the fleet of the year (t)	30,164,041.34	44,815,792
Gross value of production corresponding to a maximum sustainable yield	14,420,968	15,377,302.43
Gross value of production corresponding to a maximum economic yield	13,085,449	10,879,344
Gross value of production corresponding to sustainable yield taking into account the biomass of the year (t)	14,158,812	13,206,316

Turnover of the deep-water pink shrimp: Regarding fleet turnover of deep-water pink shrimp (*P. longirostris*), fleet_H, SA performed best with a turnover of US$3.404 million compared to fleet_H, fleet_G, and fleet_OP, SA in 2016-2017. In 2017-2018, fleet_H had an even higher turnover of US$5.83 million. Therefore, according to annual turnover, the fleets performed better in 2017-2018 than in 2016-2017 shown in Figure 4.

Catches and days at sea: We use the catch per unit of effort (CPUE) of industrial fishing to estimate the annual catch (kg) by the number of days at sea for fleets that target the *Parapenaeus longirostris*. The CPUEs of the COSECPRO fleets moved in somewhat the different direction. Two trends can be seen in the *P. longirostris* fleet. First, the number of days at sea for fleet_G, fleet_H, SA, and fleet_OP, SA was higher than the number of catches, and this is similar to the trend found for fleet_H in 2016-2017 illustrated in Figure 5. Second, the number of days at sea for fleet_H, SA was higher than the number of catches, which is similar to the trends for fleet_H, fleet_G, and fleet_OP, SA in 2017-2018 illustrated in Figure 6.
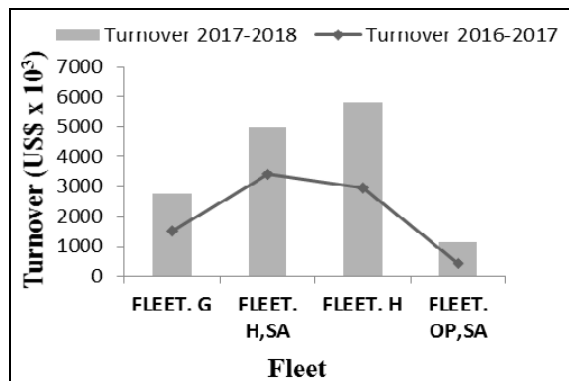
Fig 4: Annual turnover (US$ x 10^3) of *Parapenaeus longirostris* of the fishery fleet in the waters of Senegal over the period 2016-2017 and 2017-2018.
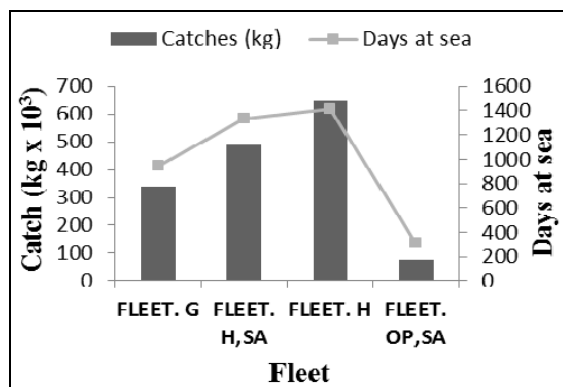
Fig 5: Total annual catches (kg x 10^3) of *Parapenaeus longirostris* by the days at sea of the fishery fleet in the waters of Senegal from 2016 to 2017.
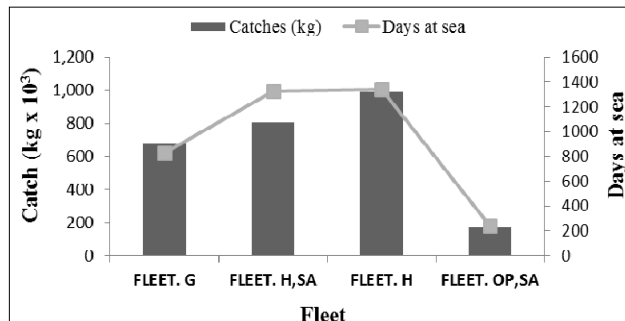
Fig 6: Total annual catches (kg x 10^3) of *Parapenaeus longirostris* by the days at sea of the fishery fleet in the waters of Senegal from 2017 to 2018.

4. Discussion and Conclusion

This paper conducts a macroeconomic analysis of deep-water pink shrimp (*Parapenaeus longirostris)* as it contributes to national economic growth. This work has highlighted the connection between the economics and management of the deep-water pink shrimp industry, as well as its weak contribution to the national GDP according to added value, which was around US$4.583 million per year. Despite its weak contribution to GDP, this product has great potential for generating wealth through exports. The deep-water pink shrimp is currently one of the most important commercial and economic species and is heavily exploited by trawl fisheries in the Atlantic area [5], particularly in Senegal. It is also one of the most important commercial catches volumes in the Mediterranean region [6]. In Morocco, it represented 98% of the landings species of the deep-water fishery [7] due to its most valuable species in fishery markets. It has also a high commercial value in France, Italy, Algeria, Tunisia, Greece, and Turkey [8, 9]. This study demonstrates the economic interest of deep-water pink shrimp and its relationship to market variables such as landing prices, relevant operating costs (e.g. maintenance, fuel, lubricant costs, etc.), and its high market value (high economic profitability) due to demand from the international market [10, 11, 12]. Additionally, a look at labor productivity and employee's physical capital (e.g. average salary) provides a social perspective to the industry [13, 14, 10].

The owners of the fishing units earn most of their gross value of production from sales on the catches. Therefore, the gross value of production of all the deep-water pink shrimp fleets was high in 2017 at US$30.164 million and even higher in 2018 at US$44.816 million showed in Table 3, an increase of US$14.652 million. Remuneration is also relatively high at a salary of US$180,809 for the crew in 2016-2017, increasing to US$242,029 in 2017-2018. This was an increase of US$61,220 due to improved catch performance and fishing effort. The catch per unit of effort (CPUE) of industrial fishing was used to estimate the annual catch (kg) by the number of days at sea of fleets that target *P. longirostris*. This CPUE shows that the number of days at sea of all the

COSECPRO fleets was sometimes higher than catches while sometimes less than the catches from 2016-2017 to 2017-2018 showed in Figure 6. This can be explained by the inter-annual variation of the pink shrimp, and it can, therefore, be said that the fishing effort of these fleets has contributed to slight overexploitation of this species.

Overall, in the deep-water shrimp fisheries sector, the effects of taxes and subsidies are mixed. Taxes and subsidies are common for all fisheries and generally relate to fuel, the import of vessels, and fishing gear acquisition.

In order to advance the potential economic interests of the fisheries sector, management measures and fishery policy instruments have been established to protect this resource and to promote economic performance. These measures pertain to the terms of access, fishing zones, gear mesh, individual transferable quotas, electronic fishing logbooks, catch control, embedded observers, and a penalty for exceeding the total allowable catch. It was also defined who can fish and under what conditions. Therefore, it is necessary to develop public policies that place the fishermen at the heart of the reform. The optimal exploitation and preservation of this short-lived species by profit-seekers are general determinants for ex-vessel prices, market prices, demand, and supply of the deep-water pink shrimp under imperfect competition [15]. In conclusion, the effective management measures that reduce the exploitation pressure on deep-water pink shrimp are imperative in order to reduce demand by Western countries. These management measures should also focus on evenly distributing benefits and increasing the contribution of this industry to national GDP by increasing fishers' income. We also argue that fisheries must be seen in the context of the economy and society as a whole. Using this mindset, relevant stakeholders should work to conserve deep-water pink shrimp for all of society into the future so that it does not become depleted due to profit maximization.

5. References

1. United Nations Environmental Program (U.N.E.P). Policy Implementation and Fisheries Resource Management: Lessons from Senegal. Fisheries and the Environment, 2004.
2. Ministère de la Pêche et de l'Economie Maritime (M.P.E.M). Décret n° 2013-246 du 11 Fevrier 2013 portant approbation du Plan d'Aménagement de la Pêcherie de Crevette Profondes. Convention de concession des droits de pêche et de gestion de la pêcherie de crevettes profondes au Sénégal entre le MPEM et la COSECPRO, Dakar, Sénégal, 2015.
3. Meissa B, Fall M, Thiam N, Thiaw M, Ba K, Thiam M. Modélisation biologique: Evaluation des principaux stocks démersaux exploités au Sénégal Programme Aménagement Durable des Pêches au Sénégal, CRODT, Dakar, Sénégal, 2017.
4. FAO. The value of African fisheries. Rome, Italy, 2014, http://www.fao.org/3/a-i3917e.pdf. 17 January, 2019.
5. Sobrino I, Garcıa T, Baro J. Trawl gear selectivity and the effect of mesh size on the deep-water rose shrimp (*Parapenaeus longirostris*, Lucas, 1846) fishery off the gulf of Cadiz (SW Spain). Fisheries Research. 2000; 44:235-245.
6. Brutto SL, Maggio T, Arculeo M. Isolation By Distance (IBD) signals in the deep-water rose shrimp *Parapenaeus longirostris* (Lucas, 1846) (Decapoda, Panaeidae) in the Mediterranean Sea. Marine Environmental Research. 2013; 90:1-8.
7. Benchoucha S, Berraho A, Bazairi H, Katara I, Benchrifi S, Valavanis VD. Salinity and temperature as factors controlling the spawning and catch of *Parapenaeus longirostris* along the Moroccan Atlantic Ocean. Hydrobiologia. 2008; 612:109-123.
8. Holthuis LB. FAO Species Catalogue. Shrimps and Prawns of the World. An Annotated Catalogue of Species of Interest to Fisheries. FAO Fish Synopsis. 1980; 125:271.
9. Sbrana M, Viva C, Belcari P. Fishery of the deep-water rose shrimp *Parapenaeus longirostris* (Lucas, 1846) (Crustacea: Decapoda) in the northern Tyrrhenian Sea (Western Mediterranean). Hydrobiologia. 2006; 557:135-144.
10. Ceriola L, Accadia P, Mannini P, Massa F, Milone N, Ungaro N. A bio-economic indicators suite for the appraisal of the demersal trawl fishery in the Southern Adriatic Sea (Central Mediterranean). Fisheries Research. 2008; 92:255–267.
11. Ramírez-Rodríguez M. Data collection on the small-scale fisheries of Mexico. ICES Journal of Marine Science. 2011; 68:1611-1614.
12. Prellezo R, Accadia P, Andersen JL, Andersen BS, Buisman E, Little A *et al*. A review of EU bio-economic models for fisheries: the value of a diversity of models. Marine Policy. 2012; 36:423-431.
13. Hundloe TJ, Rose R, Stubbs M, Gooday P, Cox A. Economic performance indicators for fisheries. Marine and Freshwater Research. 2000; 51:485-491.
14. Somot S, Sevault F, Deque M. Transient climate change scenario simulation of the Mediterranean Sea for the twenty-first century using a high-resolution ocean circulation model. Climate Dynamics. 2006; 27:851-879.
15. Kube R, Löschel A, Mertens H, Requate T. Research trends in environmental and resource economics: Insights from four decades of JEEM. Journal of Environmental Economics and Management. 2018; 92:433-464.