Subsidies, Fisheries Management and Stock Depletion*

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Abstract

This paper investigates the impact of fishery subsidies on resource stocks in 23 OECD countries during 1996-2011. Results show that the effect of subsidies depends on the type of subsidy and the management regime. Within this sample, cost reducing subsidies have no effect on stocks if management is individual quota-based but have negative effects if management uses traditional input/output restrictions. Subsidies for improving fishery management and infrastructure produce beneficial effects on stocks under traditional management, but no effect with individual quota-based management. These results suggest global efforts to reform fishery subsidies should be carried out in a highly selective manner.

Keywords: Fishery subsidies, OECD, overfishing, individual quota-based management, WTO
JEL Classification: Q22, Q28

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I. INTRODUCTION

The debate over possible new rules for fishery subsidies has not been settled in spite of a decade of discussion in the Doha Round of the World Trade Organization (WTO).[1] Complicating the debate is the common-property nature of the fishery resources since the state of regulation may be a key factor determining whether subsidies exacerbate or ameliorate the overexploitation of fish stocks. This is a real concern because annual fishery subsidies are large - with one estimate suggesting a figure of 34 US$ billion worldwide.[2] While subsidies lowering the costs of fishing are generally perceived as harmful, subsidies related to fishery management are more controversial. Given the overexploited state of many fishery resources, a resolution to this debate should not wait any longer.

As a step towards resolution, this paper uses a panel of data from 23 OECD countries for the 1996-2011 period to estimate the impact of subsidies on fish stocks. To do so, I match country level subsidy data with a resource stock index prepared by the Sea Around Us Project (SAUP).[3] Since the impact of subsidies is likely to vary by type, subsidies are grouped into three categories: income related Direct Payments, Cost Reducing Transfers, and subsidies to management and infrastructure investments that represent General Services.[4] Finally, as the debate has made clear the impact of subsidies is likely a function of existing fisheries management policies (UNEP 2004), I allow for two different management regimes: individual quota-based (e.g., IQ and ITQ) management and traditional input/output management. This distinction is likely to be important since individual quota-based management requires stricter monitoring and enforcement, and is expected to be more effective in protecting resource stocks than traditional input/output management (OECD 2006a; Munro et al. 2009).

There are a number of difficulties in identifying the effect of fishery subsidies on resource stocks. The first difficulty concerns data availability. Because stock assessment is available for only a limited number of fish stocks, we have to use harvests or harvest oriented indices for resource stocks. These measures, however, require special care with regard to when the effect will materialize. Subsidies could boost the harvest in the short-term, but decrease it in the longer-term through resource degradation (and vice versa). If we do not distinguish between these short- and long-term changes, we may mistakenly interpret the short-term increase in harvest as a resource recovery. To deal with this issue, the relationship is examined between current resource stocks and past subsidies using different lag structures. As the number of lags increases, the long-term effect of subsidies should emerge in the parameter estimate.

Second, subsidies and resource stocks may both be correlated with another variable. For example, economic fluctuations could affect both the budget for subsidies and the demand for fishery products (which affects resource stocks). To deal with this issue, the panel structure of the data is exploited and used to control for both country and year fixed effects. Even with these controls in place, it is possible that other unobservable country-specific time-varying factors may also play a role; for example, change in input or output prices may affect

[1] The WTO has no clear definition of fishery subsidies. A broad range of government spending is discussed as potential subsidies, including spending for research and management of the fishery.

[2] This amounts to more than one third of the world fishery production value. See Sumaila and Pauly (2006) and FAO (2009).

[3] See Pauly and Zeller (2015).

[4] Due to data limitation, management and infrastructure investments cannot be separated.

fishers' behaviour and also affect fishery policies. Therefore I include both import price of oil products and fishery products in the estimation to control for input and output price fluctuations.

Finally, there are potential issues with reverse causality that need to be considered. Fishery subsidies might cause resource decline, while at the same time resource decline might in turn call for government interventions such as subsidies.[5] Although one cannot entirely exclude the possibility of reverse causality, it seems less of a concern in the present work. Since the paper examines the relationship between past subsidies and current resource stocks, reverse causality means that current resource stocks affect past subsidies. This can happen when fishers demand subsidies based on the expectation of future resource stocks. As the number of lags becomes larger, however, the magnitude of uncertainty becomes larger and is likely to dominate the effect of expectations. Hence, reverse causality should produce minimal bias in the present context. The validity of this assumption is examined in Appendix A.

Overall, my results are consistent with the literature in that the impact of subsidies is conditional on the management regime in place, as well as dependent on the exact form the subsidy takes. Within the sample, my empirical results show that all three types of fishery subsidies have little effect in countries with individual quota-based management. However, in countries with traditional input/output management schemes, Cost Reducing Transfers today decrease the harvest of healthy stocks five years later,[6] while General Services today increase that of healthy stocks five years later. Direct Payments also decrease resources, but the effect is only marginally significant.

There is a large volume of literature addressing the issues of fishery subsidies. Some of this literature is descriptive in categorizing and estimating the value of fishery subsidies generally (Sumaila and Pauly 2006; Sumaila et al. 2010; Milazzo 1998), or providing estimates for specific countries (Sharp and Sumaila 2009; Mesnil 2008). Estimates of total subsidy values are upwards of 34 US$ billion. These papers typically assume open access fisheries and argue that cost-reducing subsidies decrease resources stocks.

The second strand of literature advances toward identifying the conditions under which subsidies affect resource stocks. This literature has developed using bio-economic models of the fishery evaluated using comparative statics (Munro and Sumaila 2002; Sumaila et al. 2008). The general conclusion here is that subsidies lead to overexploitation of resources in open access fisheries. However, fisheries with a proper level of harvest control can avoid overfishing. A corollary of this work is that the effect of subsidies depends on fisheries management programs in place. An interesting extension in international trade shows subsidies in one country may have spillover effects though the world price of fish (Brander and Taylor 1997; Jinji 2012; Bayramoglu et al. 2014).

The empirical work on subsidies is not extensive but the work by Yagi et al. (2008), Yagi et al. (2009) and Sumaila et al. (2013) are most closely related to the work at hand. Yagi

[5]For example, after the collapse of Northern Atlantic Cod stocks in the late 1980s, the Canadian government established a number of programs including income maintenance to support the fishing industry (Schrank 2003).

[6]Healthy stocks refer to the stocks who are categorized as developing, exploited or rebuilding according to the SAUP criteria. The stated change in resource stocks occurs within a single year. The aggregate change in resource stocks over time will be larger, but that is beyond the scope of this paper.

et al. (2008) evaluate the empirical effects of subsidies on fishery production. A panel of 23 OECD countries, 1996-2002, is used to show that income subsidies increase harvest while management and infrastructure subsidies have the opposite effect. Yagi et al. (2009) use a similar analysis for Japanese time series data for the period 1971-2003 and find a positive effect of "Government other general services" on production value per fishers. Sumaila et al. (2013) use cross-section data of 37 island countries and examine the effect of subsidies on fish stocks. They find a negative relationship between "bad" subsidies and fish resources. Though suggestive, these studies either ignore the long-term effect of subsidies or ignore unobservable heterogeneity across countries. Moreover, none of them consider the potential role of fishery management.

II. DATA

Subsidy data is available from a series of OECD Review of Fisheries publications.[7] The data set covers the period 1996-2011 and includes three types of fishery subsidies: Direct Payments, Cost Reducing Transfers and General Services.[8] Direct Payments are primarily directed at increasing the income of fishers, and thereby correspond to income subsidies. Examples include grants for new vessels and vessel decommissioning. This category also includes revenue enhancing subsidies such as market price support. Cost Reducing Transfers reduce fixed or variable costs of fishing. Interest subsidies and fuel-tax exemptions fall into this category. General Services corresponds to transfers for fisheries management and the development of infrastructure. Definitions and examples of each category are found in Table 1.

Because each country has a different size of fishing industry, the amount of fishery subsidies must be normalized to make it comparable across countries. As reliable data on the number of fishers in each country is not available, the output value of fishing industry in each country is used for the normalization. One concern is that the output value itself can be endogenous in the present context. For example, meteorological conditions on fishing grounds may affect both output values and resource stocks, thereby potentially inducing omitted variable bias in estimation. To minimize this concern, fishery subsidies are normalized by the "average" output value over time in each country. The average output value is constant over time, so any factors that are correlated with them are controlled for by country fixed effects included in estimation.[9]

[7]These reports contain data of government financial transfers, which are defined as "the monetary value of government interventions associated with fisheries policies". Because there is no internationally agreed definition on fishery subsidies, the government financial transfers are treated as subsidies in this paper, following two closely related studies (Yagi et al. 2008, 2009).

[8]Missing observations are a serious problem with the subsidy data. For example, while 23 countries over 16-year period amounts to 368 observations, the number of observations for Cost Reducing Transfers is only 280 as shown in Table 3. Various OECD reports are used to obtain as complete a series as possible. The general survey section of a series of "Review of Fisheries in OECD Countries: Policies and Summary Statistic" is the main source of subsidy data, but it includes a lot of missing observations. To mitigate this issue, I read through the country note sections of these reports, because they sometimes include data that is not reported in the general survey section. Further, a series of "Review of Fisheries in OECD Countries: Country Statistics" and OECD (2006a, 2006b) are used to complement the data.

[9]Simple normalization using the output values gives qualitatively similar results.

Table 1: Definitions and examples of fishery subsidies (OECD 2000)

Type	Definition	Examples
Direct Payment	Payments from government to fishers and are primarily directed at increasing the income of fishers.	Price support, Grants for new vessels, Grants for modernization, Grants for temporary withdrawal of fishing vessels, Vessel decommissioning, Income support, Unemployment insurance
Cost Reducing Transfer	Payments aimed at reducing the costs of fixed capital and variable inputs.	Subsidized loans for vessel construction/modernization, Interest subsidies, Fuel tax exemption, Government payments of access to other countries' water
General Service	Payments which are not necessarily received directly by fishers but nevertheless reduce the costs faced by fishers.	Management expenditure, Enforcement expenditure, Expenditure for information collection and analysis, Aid for restocking of fish resource, Support to build port facilities for commercial fisheries

Measure for resource stocks

The measure of resource stocks[10] used in empirical work is based on the Fish Stock Overexploited or Collapsed (FSOC) index developed by the SAUP and extended by Hsu et al. (2014). The index is defined for country i at year t and based on harvest in each country's Exclusive Economic Zone (EEZ). The FSOC index function[11] is written:

$$FSOC_{it} = \frac{\text{Harvest of stocks Overexploted or Collapsed in EEZ}_{it}}{\text{Total harvest of stocks in EEZ}_{it}} \tag{1}$$

Overexploited and Collapsed stocks are based on a five category stock classification used by the SAUP.[12] For ease of interpretation, this paper uses the following modified version of the

[10] The SAUP defines the number of "stocks" as a time series of a given species, genus or family (higher and pooled groups have been excluded) for which the first and last reported landings are at least 10 years apart, for which there are at least 5 years of consecutive catches and for which the catch in a given area is at least 1000 tonnes.

[11] The index can be modified to examine the effect of catch share systems on resource stocks (Costello et al. 2008).

[12] The SAUP notes that stock-status categories are defined using the following criteria (all referring to the maximum catch [peak catch] or post-peak minimum in each series): Developing (catches $\leq$ 50% of peak and year is pre-peak, or year of peak is final year of the time series); Exploited (catches $\geq$ 50% of peak catches);

FSOC (MFSOC) index:

$$MFSOC_{it} = (1 - FSOC_{it}) * 100 \tag{2}$$

Therefore, an increase in the MFSOC index corresponds to an increase in the harvest of developing, exploited, or rebuilding stocks, given the total harvest for country i at year t. The MFSOC has the advantage that an increase in the index corresponds to an increase in resource stocks.

Froese et al. (2012) argue that harvest-based resource indices perform reasonably well in capturing trends in biomass but respond to a decline in biomass in a delayed fashion. This means that short-term fluctuations in these indices do not necessarily reflect resource fluctuations. Fishery subsidies possibly boost harvests in the short-term but decrease them in the long-term through resource degradation (and vice versa). Short-term changes in the index should capture the effect on harvest, but not on resource stocks. Therefore, this paper focuses on the long-term changes in the MFSOC index.

The interpretation of the MFSOC index requires further caution because it changes both at the intensive and extensive margins. At the intensive margin, harvest of stocks in each category (as defined by the SAUP) changes without re-categorizing these stocks. At the extensive margin, changes in harvest lead to re-categorizing of these stocks. For example, when the harvest of an overexploited stock increases, the MFSOC index first decreases (intensive margin), and when the harvest exceeds a certain threshold and the stock is re-categorized as "Rebuilding", the index increases (extensive margin). Detailed data is not available, however, to distinguish between the intensive and extensive margins. Hence, all changes in the index are presumed to be from the extensive margin. This may be reasonable given that the focus of this paper is the long-term effect of subsidies.

The 23 countries used in this study are divided into two groups; Quota countries, with fisheries management based on individual quota (IQ) or individual transferable quota (ITQ) systems, and Non-Quota countries with fisheries management based on traditional input/output restrictions. Quota based fisheries management typically allocates a fixed amount (or a proportion) of fishing quota to individual (or a group of) agents, with an intention to avoid the common-pool resource problem. Quota based systems require strict monitoring and enforcement of the total output restriction to avoid overfishing.[13] Country classification by management type is shown in Table 2.[14]

Over-exploited (catches between 50% and 10% of peak and year is post-peak); Collapsed (catches < 10% of peak and year is post-peak); and Rebuilding (catches between 10% and 50% of peak and year is after post-peak minimum).

[13]According to OECD (2006b), "The enforceability issue is indeed one of the salient challenges faced by IQs systems. It depends on Monitoring, Control and Surveillance (MCS) capacities...". Copeland and Taylor (2009) argue that the regulators enforcement power is a key to determine success in resource management. Munro et al. (2009) argue that quota-based management makes it easier to monitor harvests. Nevertheless, there are examples where quota-based management collapsed under an inability to monitor harvests (Cancino et al. 2007).

[14]The country classification is based on an overview of fisheries management by (OECD 2006b). It reports which country uses IQ or ITQ management systems, but does not report the extent to which a given system is used or how effective it is to manage fisheries in each country. It is also possible that countries that use quota systems are mistakenly reported as not using these systems. Hence, "quota countries" in this paper

Table 2: List of Quota and Non-Quota countries

15 Quota countries	8 Non-Quota countries
Australia, Canada, Denmark, France, Germany, Iceland, Italy, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, UK, USA	Finland, Greece, Ireland, Japan, Korea, Mexico, Sweden, Turkey

Summary statistics are provided in Table 3, where all prices are in 2009 US$. The MFSOC index shows that on average over all countries, 83% of fish stocks are at the developing, exploited, or rebuilding stage. The lowest value 75.91 is observed in the UK in 2008 while the highest value 91.74 is observed in Greece in 1996. The total value of subsidies is on average 27% of the total landing value. The breakdown across subsidies from smallest share is 4% Cost Reducing, 5% Direct Payments and by far the largest at 18% is General Services. Also, General Services have the largest coefficient of variation 0.75, in contrast to 0.5 for the other two categories. Note the very large standard deviation for General Services is caused by Japan reporting more than 10 times the average value in the sample.[15] The import prices of fish products and oil products are used as control variables in the estimation.[16] Finally, the Quota-based management indicates that 67 percent of the sample countries are categorized as quota regulated countries.

Table 3: Summary statistics

Variable	N	Mean	SD	Min	Max
MFSOC index	368	83.32	2.19	75.91	91.74
Total subsidies / average revenue	267	0.27	0.33	0.00	2.26
Direct Payments / average revenue	314	0.05	0.10	0.00	1.31
Cost Reducing Transfers / average revenue	280	0.04	0.08	0.00	0.47
General Services / average revenue	349	0.18	0.24	0.00	1.79
Import price of fish products (USD/kg)	368	3.18	1.44	0.43	7.06
Import price of oil products (USD/kg)	368	1.43	1.07	0.04	6.55
Share of green party	368	1.59	2.75	0.00	11.60
Quota-based management	368	0.65	0.48	0.00	1.00

Notes: The sample covers the period 1996-2011, and consists of 23 OECD countries: Australia, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Turkey, UK and USA

should be interpreted as countries that are using quota systems relatively more intensively, on average, than "non-quota countries". In the absence of a country level fisheries management database, this seems to be the best possible way to classify these countries.

[15] One potential reason is that the entire infrastructure-related budget is managed by the fishery agency in Japan, while some of the infrastructure-related budgets are managed by other agencies in other countries (Yagi 2008).

[16] The import price of fish products comes from the FAO Fish Stat Plus, while the that of oil products is constructed from the "value of oil imports" from the International Monetary Fund and the "volume of crude oil products" from the OECD.stat.

III. ESTIMATION

Econometric model

This section examines the effect of three types of fishery subsidies on resource stocks. The equation of interest and the identification assumption are respectively given by:[17]

$$
\begin{aligned}
MFSOC_{it} = {} & \rho_{1k} DP_{it-k} * Quota_i + \rho'_{1k} DP_{it-k} * (1 - Quota_i) \\
& + \rho_{2k} CRT_{it-k} * Quota_i + \rho'_{2k} CRT_{it-k} * (1 - Quota_i) \\
& + \rho_{3k} GS_{it-k} * Quota_i + \rho'_{3k} GS_{it-k} * (1 - Quota_i) \\
& + \gamma X_{it-k} + \alpha_i + \mu_t + u_{it} \quad \text{for} \quad k \in \{1, 2, ..\}
\end{aligned} \tag{3}
$$

$$
E[u_{it} | \alpha_i, \mu_t, DP_{it-k}, CRT_{it-k}, GS_{it-k}, X_{it-k}] = 0 \quad \text{for} \quad k \in \{1, 2, ..\} \tag{4}
$$

The outcome of interest is the MFSOC index for country i at year t. Three variables of interest, DP_{it-k}, CRT_{it-k}, and GS_{it-k} are respectively ln Direct Payments per output value, ln Cost Reducing Transfers per output value, and ln General Services per output value for country i at year t-k.[18] $Quota_i$ is an indicator variable that takes 1 if a country is categorized as a Quota country and 0 otherwise. X_{it-k} includes the import price of fish and oil products as proxies for input and output prices, α_i and μ_t are country and time fixed effects, respectively, and u_{it} is the unobserved error term. Since Japan is a clear outlier in terms of General Services, an interaction term of Japan Dummy and General Services is also included in the equation.[19]

I estimate the model using a different number of lags to examine the short- and long-term effects.[20] Due to the short time-dimension of the data, up to 6 lags are considered. One may question this specification in that subsidies in different time periods are not included together in the model; if subsidies have both short- and long-term effects, it is more appropriate to include subsidies at different time periods together in the model to separately identify these effects. This does not seem to be a serious issue in the present context, however, because serial correlations in subsidies are not so strong as to significantly affect results. Adding various lags at the same time does not change the conclusion of this paper. Further, subsidies with short time lags are more likely to be affected by reverse causality, so it is better not to include them to identify the effect of subsidies with longer time lags.

The equation includes country fixed effects so that a given country is compared to itself across years that have higher or lower amounts of subsidies. These fixed effects therefore eliminate sources of omitted variable bias generated by across-country differences that are

[17]An alternative specification is to estimate the equation separately for two groups of countries without the quota dummy variable. As shown in Appendix B, results are similar, but less precise when estimated separately due to the small sample.

[18]For observations that take 0, I added 1 before the ln transformation. This does not change the results qualitatively, but allows more precise inferences.

[19]Excluding Japan from the sample changes the results only marginally.

[20]Another approach for examining the timing of effects is to use the aggregated data over a different number of years, while keeping the number of lags in the estimation as 1. See Acemoglu et al. (2008) as an example. Unfortunately, due to the short time dimension and the large number of missing observations, this approach is infeasible.

constant over time and may be correlated with different amounts of subsidies. Difference in the productivity of fishing grounds and the public tolerance for subsidy are therefore controlled for in estimation.

The identification assumption means that subsidies are allocated as good as random after controlling for the fixed effects and other covariates. This assumption excludes the possibility of reverse causality. Because the independent variables are lagged, reverse causality means that fishers and fishery managers ask or allocate subsidies based on the expectation of the future resource. As the number of lags become larger, however, the magnitude of uncertainty becomes larger and likely dominate the effect of future expectation. Therefore, reverse causality is expected to produce minimal bias in the present context. The validity of this assumption is examined in Appendix A.

Results

The results are shown in Table 4. The first three rows correspond to Quota countries while the next three correspond to Non-Quota countries. As we move from left to right in the table, the lag of subsidies (k) increases from 1 to 6.

Table 4 exhibits a number of interesting features. First of all, fishery subsidies have significant effects only in Non-Quota countries. This is an indication of the heterogeneous effects of subsidies across management. In Quota countries, only Cost Reducing Transfers (CRTs) with a 4-year lag show a significant effect. CRTs with 3-year or 5-year lags, however, do not show any effects. Further, point estimates for these lags are notably different from that of the 4-year lag. Hence, this could be an artifact of the large missing observations in CRTs.

Second, in Non-Quota countries, Direct Payments (DPs) show a significant and negative association with resource stocks with 4 and 5-year lags. This seems reasonable since DPs include many effort-enhancing subsidies. DPs also include vessel buyback programs that are generally believed to be beneficial for resource conservation. As Clark et al. (2005) argue, however, these subsidies could be harmful if vessel buyback programs are anticipated by fishers and induced investment for the fishing capacity occurs. The result is in line with their argument.

Third, Cost Reducing Transfers (CRTs) show a strong negative effect with 3 - 5 year lags. It is worth pointing out that the point estimate with a 1-year lag is positive. This seems reasonable if CRTs boost harvest in the short-term but decrease it in the long-term through resource degradation. The MFSOC index increases first with the boost in harvest, but decreases later with resource degradation.

Finally, General Services (GSs) show the opposite of CRTs. It has a significant and negative effect with a 1-year lag, but a significant and positive effect with 4 - 6 year lags. This seems reasonable if GSs are spent on the stricter enforcement of fishery management. This could reduce harvest in the short-term, but increase it in the long-term through resource recovery. The MFSOC index decreases with stricter management, but later increases with the resource recovery.

Table 4: Three subsidies in both groups of countries

	Dependent variable: MFSOC index					
	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
Quota:						
- DP	0.022	0.039	-0.104	-0.142	-0.108	0.021
	(0.065)	(0.069)	(0.093)	(0.104)	(0.168)	(0.163)
- CRT	0.010	0.031	0.078	0.272[a]	0.138	-0.100
	(0.029)	(0.041)	(0.057)	(0.088)	(0.086)	(0.191)
- GS	0.168	0.099	-0.034	-0.205	0.010	0.021
	(0.169)	(0.182)	(0.188)	(0.163)	(0.242)	(0.167)
Non-Quota:						
- DP	-0.204	-0.247	-0.251	-0.339[b]	-0.408[c]	0.073
	(0.212)	(0.248)	(0.207)	(0.123)	(0.212)	(0.274)
- CRT	0.003	-0.030	-0.119[a]	-0.128[a]	-0.117[a]	-0.061[b]
	(0.077)	(0.064)	(0.035)	(0.026)	(0.026)	(0.022)
- GS	-0.088[a]	-0.048	0.709[c]	0.664[c]	0.775[a]	0.759[a]
	(0.028)	(0.046)	(0.394)	(0.346)	(0.249)	(0.151)
- GS*Japan	0.048[c]	0.016	-0.744[c]	-0.714[b]	-0.835[a]	-5.651[a]
	(0.024)	(0.045)	(0.385)	(0.343)	(0.253)	(0.946)
N	244	226	209	192	177	160
Countries	23	23	23	23	23	23
R2	0.377	0.356	0.375	0.325	0.272	0.212
RMSE	1.010	0.990	0.965	0.934	0.949	0.980

Notes: Standard errors are clustered at the country level. a, b, and c mean statistical significance at the 1 %, 5%, and 10% levels, respectively. All the specifications include country and year fixed effects, and input/output prices as control variables. DP: Direct Payments, CRT: Cost Reducing Transfers, GS: General Services.

Robustness check

In this section, I check the robustness of the estimated impacts of fishery subsidies on resource stocks. I treat the main result with a 5-years lag as a base line, which is shown in Column 1 of Table 5. In Column 2, I include a 5-year lagged dependent variable as an additional control. If fishery managers decide the amount of subsidies in each period based on resource stocks in the respective period, the resource stocks in that period can be a source of omitted variable bias. The estimate is quite similar to the main result.

In Column 3, I re-categorize Japan and Korea as Quota countries. These two countries do not implement IQ or ITQ management, but they do implement community-based quota management (OECD 2006b). If communities can manage fishery well, these countries may have more effective output restrictions than the other Non-Quota countries. The result does not change qualitatively, though the point estimate for GSs is somewhat smaller.

In Column 4, I exclude Australia, France, Netherlands, the United Kingdom, and the United States from the estimation because they report "bad" harvest data for one or more EEZ (Hsu et al. 2014). As all of these countries are categorized as Quota-countries, the parameter estimates for Non-Quota countries changes little.

In Column 5, I use data only up to 2006 because the method used for constructing the FSOC (and MFSOC) index is different before and after 2006 (Hsu et al. 2014). Up to 2006, the index is calculated by the SAUP. It has, however, not published the index after 2006, so the EPI calculates the index using an "ad-hoc" method. This raises a concern for the consistency of the data. Using the data up to 2006 does not change the result qualitatively.

Finally, in Column 6, I use an alternative outcome variable for the estimation. The outcome variable here (MFSOC2 index) is the share of the "number" of fish stocks in an EEZ that are developing, exploited, or rebuilding. As discussed, the MFSOC index changes both at the intensive and extensive margins. This introduces some ambiguity in the interpretation of the results. The new index here has the advantage that it changes only at the extensive margin.[21] Therefore, if the result using this index is similar in terms of signs, it supports the presumption that the main results capture the changes at the extensive margin. The result is quite similar in terms of signs of parameter estimates.

IV. DISCUSSION

The previous section suggests that in countries with individual quota-based management, subsidies have little effect on resource stocks. This seems a reasonable conclusion if individual quota-based management effectively limits the total harvest at a sustainable level. However, such a presumption is somewhat naive because a number of conditions are required in order for individual quota-based management to work effectively. For instance, Grafton (1996) notes that ITQ management maximizes the economic rent of a fishery only when in-season stock externalities and congestion externalities are absent. Further, he notes that without fishers' compliance with regulations, individual quota management can be detrimental to a fishery. Similarly, Bromley (2009) discusses, from various points of view, how the existence of an individual fishing quota system is neither a necessary nor a sufficient condition for successful management. This earlier research suggests that cost-reducing or capacity-enhancing subsidies could have a detrimental effect on resource stocks even under individual quota-based management.

Along similar lines, Munro and Sumaila (2002) discuss the consequence of a more extreme form of harvesting rights — the full privatization of fishery. They show that cost-reducing subsidies can decrease resource stocks even under full privatization, and resource stocks can be driven down to extinction levels. Further, Clark et al. (2010) argue that the possibility of single owners finding it optimal to drive the resource to extinction should not be dismissed out of hand. While I find little effect of subsidies on resource stocks under individual quota-based management, these papers suggest that my result is unlikely to hold in all situations.

I also find that, in countries with traditional input/output management, Direct Payments and Cost Reducing Transfers are harmful to resource stocks while General Services are generally beneficial. Since Direct Payments and Cost Reducing Transfers both reduce the cost of fishing operations, it seems reasonable to find negative effects for these subsidies. It is less clear however why General Services appear to create beneficial effects. The answer probably

[21] A drawback is that this index is available only up to 2006.

Table 5: Robustness check

	Dependent variable					
	MFSOC	MFSOC	MFSOC	MFSOC	MFSOC	MFSOC2
Quota:						
- DP	-0.108	-0.124	-0.158	0.350	0.033	-0.543
	(0.168)	(0.152)	(0.146)	(0.202)	(0.149)	(0.565)
- CRT	0.138	0.175^c	0.081	0.194^c	-0.064	0.522
	(0.086)	(0.097)	(0.093)	(0.102)	(0.120)	(1.091)
- GS	0.010	0.016	0.187	-0.413^b	0.260	1.792^b
	(0.242)	(0.227)	(0.258)	(0.179)	(0.155)	(0.822)
Non-Quota:						
- DP	-0.408^c	-0.426^c	-0.370	-0.398^c	-0.226	0.689
	(0.212)	(0.227)	(0.254)	(0.209)	(0.359)	(0.632)
- CRT	-0.117^a	-0.099^a	-0.102^a	-0.113^a	-0.290^a	-1.088^a
	(0.026)	(0.034)	(0.027)	(0.029)	(0.049)	(0.180)
- GS	0.775^a	0.729^b	0.604^b	0.722^b	0.798^b	0.098
	(0.249)	(0.270)	(0.261)	(0.262)	(0.310)	(0.965)
- GS*Japan	-0.835^a	-0.803^a		-0.769^b	-3.152^a	-5.769
	(0.253)	(0.270)		(0.266)	(0.971)	(5.022)
LagDep	NO	YES	NO	NO	NO	NO
N	177	177	177	143	93	93
Countries	23	23	23	18	20	20
R2	0.272	0.291	0.236	0.293	0.292	0.171
RMSE	0.949	0.940	0.973	0.966	0.969	4.427

Notes: Standard errors are clustered at the country level. a, b, and c mean statistical significance at the 1 %, 5%, and 10% levels, respectively. All the specifications include country and year fixed effects, and input/output prices as control variables. Subsidy variables are lagged by 5 years. DP: Direct Payments, CRT: Cost Reducing Transfers, GS: General Services. LagDep: Lagged dependent variable. MFSOC2 stands for the share of the "number" of fish stocks in an EEZ that are developing, exploited or rebuilding. Column 1 is the baseline model with 5-year lag. Column 2 includes the 5-year lagged dependent variables as an additional control. Column 3 recategorizes Japan and Korea as Quota countries. Column 4 excludes Australia, France, Netherlands, UK and USA from the sample. Column 5 uses data up to the year 2006. Column 6 uses MFSOC2 as an alternative resource index.

lies in the fact that General Services subsidies reflect both investments in management, research, and enforcement (hereafter collectively described as management investments), and investments in infrastructure (hereafter infrastructure investments). These two investments are similar in magnitude, but potentially different in effect.[22] While management investments are generally perceived as beneficial, infrastructure investments may not be. This is because infrastructure investments may be useful for monitoring but they also reduce the cost of

[22]For 1996, 1997, and 2003, the mean and standard deviation of management investments are US$ 95 and US$ 188, respectively. The mean and standard deviation of infrastructure investments, on the other hand, are US$ 129 and US$ 484, respectively. Excluding Japan, the means and standard deviations for the former are US$ 76 and US$ 167, and those for the latter are US$ 20 and US$ 60. The magnitude of the latter becomes much smaller, but is still not negligible.

landing for fishers (UNEP 2004). Therefore, the beneficial effect of General Services could be driven by the beneficial effect of management investments dominating the negative effect of infrastructure investments. Alternatively, it could be the case that both management and infrastructure investments are beneficial for resource stocks, thus leading to the overall beneficial effect of General Services. To distinguish between these two possibilities, however, we need to wait until more data is accumulated. Until this issue is resolved, a cautious approach may be to maintain the total amount of General Services at the current level.

V. CONCLUSION

For over ten years, policy makers have been debating the efficacy of fishery subsidies. At present, no firm consensus has emerged. One of the reasons for the lack of consensus is most likely the striking lack of empirical evidence linking fishery subsidies to resource stocks. The aim of this paper was to provide such evidence.

The paper has two main findings based on panel data drawn from 23 OECD countries for the period 1996-2011. First, fishery subsidies have little effect on stocks, on average, in countries with individual quota-based management. Second, subsidies do affect resource stocks in countries without such management. In these countries, Cost Reducing Transfers are harmful while General Services are beneficial for resource stocks. Direct Payments also seem harmful, but this result is not statistically robust. These results are largely consistent with the predictions of theory; that is, subsidies that decrease the costs of fishing are harmful while those that help shift the fishery away from open access are beneficial. Some caution is however warranted. It is possible that the 16-year panel data is not long enough to detect the full effect of subsidies. Moreover, since a number of conditions are required in order for individual quota-based management to work properly, the results do not mean that the existence of such management is sufficient in preventing any harmful effects of subsidies.

With these limitations in mind, the policy implications of this paper are threefold. First, improving overall management practices should be of the highest priority in each country. In particular, the results indicate that individual quota-based management seems to be more effective in preventing any harmful effects of subsidies compared to traditional input/output management. Second, countries should keep up their effort to reduce cost-reducing subsidies. Although these subsidies are generally perceived as harmful, there has been little empirical evidence supporting such a view. My results consistently indicate that such subsidies reduce resource stocks in countries without individual quota-based management. Finally, management and infrastructure subsidies should not be categorically prohibited. At the Doha Round of the WTO, a group of countries insisted on universal or near-universal prohibitions of fishery subsidies. The results of this paper, however, oppose such an idea. A more cautious approach would be to maintain the amount of General Services at the current level until further empirical analyses clarify which subcategories should or should not be prohibited.

APPENDIX A: INSTRUMENTAL VARIABLE ESTIMATION

Econometric model

Estimations in the main text presume that reverse causality is less of a concern since lagged subsidies are used. To examine the validity of this assumption, this section aggregates subsidies over three categories to create one value and uses this as the only subsidy variable in the model. With the only one endogenous variable in the model, it is possible to discuss the direction of the potential bias. In fact, reverse causality is likely to lead to an underestimate of the causal effect in this model, because fishers are expected to ask for subsidies when they face or anticipate resource decline. The sample is limited to Non-Quota countries. The equation of interest and the identification assumption are given by:

$$MFSOC_{it} = \alpha_i + \mu_t + \rho\ AGG_{it-5} + \gamma X_{it-5} + u_{it} \tag{5}$$

$$E[u_{it}|\alpha_i, \mu_t, AGG_{it-5}, X_{it-5}] = 0 \tag{6}$$

where AGG is ln aggregate fishery subsidies per output value.

To obtain further insight, an instrumental variable estimation is implemented. The instrument used is the share of seats in parliament for green parties.[23] Green parties emerged in the 1970s and 1980s and their main concerns were and continued to be the environment and social justice. As fishery subsidies are generally believed to be harmful, with a larger share of green parties less fishery subsidies can be expected.[24]

To be a valid instrument, the share of green parties must not be affected by resource stocks. As fishing industries in OECD countries are extremely small, they are less likely to be the main reason for people to vote for green parties. Hence, this condition seems satisfied.[25] In addition, the share of green parties must not affect resource stocks other than through fishery subsidies. This is also likely to be satisfied with the same reason: given the small size of these fishing industries, fishery policies are unlikely to be of central importance in parliament. Note, however, that if green parties affect other fishery policies to enhance resource conservation, the resulting IV estimate is an underestimate of the causal effect.

Results

The results are shown in Table 6. Column 1 shows the result using a simple OLS. The parameter estimate is positive but not significant. Considering the small sample, this is probably reasonable. Column 2 shows the result including a 5-year lagged dependent variable. The point estimate becomes 6 times larger, but it remains insignificant. Column 3 shows

[23]Data on the share of green parties in Korea, Turkey, Poland, and Mexico is not included in Armingeon et al. (2012), and hence collected from various sources.

[24]For example, policies of England and Wales green party includes "MC327; The Green Party would press at EU level for an end to all subsidies that can result in increased fishing pressure, including concessionary tax rates for fuel, vessel modification and improving port and fish processing facilities." Note that this policy aims to reduce all of the three types of subsidies.

[25]The mean ratio of output value to GDP is less than 0.01 in the sample countries.

the result of the IV estimation and Column 4 shows the corresponding first stage estimation. As expected, the share of green parties is negatively correlated with the aggregate subsidies. The parameter estimate for the aggregate subsidies is now statistically significant and much larger than the OLS estimates in Column 1 and 2. Column 5 and 6 show the IV estimation including the 5-year lagged dependent variable. These results are similar to those in Column 3 and 4, though the point estimate for the aggregate subsidies becomes somewhat larger.

As discussed above, if green parties try to preserve resource stocks through other fishery policies, the IV estimates should be underestimates of the causal effect. In this regard, the results suggest that fishery subsidies are, on average across the three types, beneficial for resource stocks. Recall that, among the three categories, General Services is by far the largest both in terms of magnitude and standard deviation. Therefore, the results in this section imply that the causal effect of General Services is positive.

Table 6: Aggregate subsidy in Non-Quota countries

	Dependent variable					
	MFSOC	MFSOC	MFSOC	Subsidy	MFSOC	Subsidy
Agg Subsidy	0.013	0.074	2.368^a		2.647^a	
	(0.151)	(0.206)	(0.682)		(0.779)	
Green				-0.436^a		-0.409^b
				(0.112)		(0.122)
Estimation	OLS	OLS	IV	IV	IV	IV
LagDep	NO	YES	NO	NO	YES	YES
N	67	67	67	67	67	67
Countries	8	8	8	8	8	8
R2	0.353	0.374	.	0.225	.	0.252
RMSE	1.297	1.288	2.169	0.770	2.261	0.764
Fstat				15.097		11.237

Notes: Standard errors are clustered at the country level. a, b, and c mean statistical significant at the 1 %, 5%, and 10% levels, respectively. All the specifications include country and year fixed effects, and input/output prices as control variables. LagDep: Lagged dependent variable. Fstat: First stage F statistics.

APPENDIX B: SEPARATE ESTIMATIONS

Estimations in the main text use all the observations while allowing Quota and Non-Quota countries to have different parameters for subsidy variables. This raises a concern that the results may be driven by this particular specification.[26] To show this is not the case, Table 7 and 8 present separate estimates for Quota and Non-Quota countries, respectively. Although standard errors are larger than those in the main text due to the smaller sample size, point estimates are overall similar in magnitude and sign. This assures that it is not the particular specification that generates these point estimates. The specification simply increases the degrees of freedom in the estimation.

[26] I thank an anonymous referee for pointing this out.

Table 7: Three subsidies in non-quota countries

	Dependent variable: MFSOC index					
	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
Non-Quota:						
- DP	-0.368^{b}	-0.369^{c}	-0.470^{b}	-0.577^{a}	-0.442	0.231
	(0.135)	(0.162)	(0.162)	(0.146)	(0.275)	(0.156)
- CRT	-0.010	-0.040	-0.119^{a}	-0.106	-0.058	0.026
	(0.067)	(0.052)	(0.031)	(0.060)	(0.057)	(0.061)
- GS	-0.048	-0.030	0.581	0.545	0.536	0.553
	(0.037)	(0.059)	(0.318)	(0.400)	(0.435)	(0.299)
- GS*Japan	0.058	0.071	-0.543	-0.534	-0.536	-2.323
	(0.047)	(0.085)	(0.314)	(0.404)	(0.448)	(2.412)
N	88	82	76	70	65	59
Countries	8	8	8	8	8	8
R2	0.529	0.459	0.491	0.432	0.435	0.427
RMSE	1.089	1.183	1.171	1.204	1.217	1.254

Notes: Standard errors are clustered at the country level. a, b, and c mean statistical significance at the 1 %, 5%, and 10% levels, respectively. All the specifications include country and year fixed effects, and input/output prices as control variables. DP: Direct Payments, CRT: Cost Reducing Transfers, GS: General Services.

Table 8: Three subsidies in quota countries

	Dependent variable: MFSOC index					
	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
Quota:						
- DP	0.012	0.023	-0.079	-0.148	-0.119	-0.077
	(0.070)	(0.061)	(0.094)	(0.094)	(0.171)	(0.119)
- CRT	0.001	0.004	0.014	0.130^{b}	0.039	-0.065
	(0.033)	(0.040)	(0.047)	(0.047)	(0.089)	(0.194)
- GS	0.118	0.075	-0.023	-0.142	-0.042	-0.129
	(0.150)	(0.149)	(0.150)	(0.123)	(0.197)	(0.159)
N	156	144	133	122	112	101
Countries	15	15	15	15	15	15
R2	0.547	0.598	0.578	0.509	0.412	0.394
RMSE	0.798	0.692	0.678	0.643	0.648	0.616

Notes: Standard errors are clustered at the country level. a, b, and c mean statistical significance at the 1 %, 5%, and 10% levels, respectively. All the specifications include country and year fixed effects, and input/output prices as control variables. DP: Direct Payments, CRT: Cost Reducing Transfers, GS: General Services.

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