A time-series data analysis to examine effects of subsidies to fishery productions in Japan

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Abstract A cointegration analysis is conducted to examine the effect of fishery subsidies on fisheries production using data compiled over more than 30 years in Japan. The results illustrate that one fishery production indicator (production value per fishermen) shows a positive relationship with one particular group of government financial transfer (GFT) (that is, government general service expenditures including cost for fishery managements, scientific researches, and other administrative activities). No other tested results between GFTs and fishery indicators showed a real relationship. Although further scrutiny is awaited, this study could provide an empirical basis for an argument that, under an effective fishing management system, fisheries subsidies do not necessarily cause production increases or negative impact on fishing stocks.

Keywords Cointegration · Fisheries subsidies · OECD · WTO

Introduction

The World Trade Organization (WTO) started a new negotiation on fisheries subsidies in 2001. Among the participants in this negotiation, opinions are divided on the potential effect caused by subsidies. A particular issue relates to whether an empirical link between subsidies and trade distortions or other harmful effects can be demonstrated [1]. No empirical analysis has been conducted on this issue to date, although some theoretical illustrations were presented on the nature of the possible effects caused by the subsidies, e.g., by the Organization for Economic Cooperation and Development (OECD) [1] and the United Nations Environment Programme (UNEP) [2].

The purpose of this analysis is to examine the effect of fishery subsidies on fisheries production using publicly available data in Japan.

Materials and methods

An econometric method, known as cointegration analysis, was employed to analyze the data from 1971 to 2003. The data used in the analysis are listed in Table 1. Brief explanations of the data are provided in the following sections.

Data for government financial transfers in Japan

No definition of fisheries subsidies has been agreed by the WTO or other intergovernmental bodies. Without stepping into the problem of this definition, our analysis in this paper makes use of the concept of government financial transfer (GFT), which is defined as "the monetary value of government interventions associated with fisheries policies" [1] by the OECD.

The OECD [1] classifies GFTs into three categories: (1) direct payment, (2) cost reducing transfer, and (3) general service. Direct payment is characterized as payments "primarily directed at increasing the income of fishers" [1]. Only one direct payment program in Japan is its fishing fleet reduction program. Cost reducing transfer is a

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Table 1 List of variables related to GFT and fisheries production used for the cointegration analysis

Variables	Descriptions	Data sources
M_1	GFT: Direct payment	Fisheries Agency, MAFF, Japan [consumer price index (CPI) deflated]
M_2	GFT: Cost reducing transfer	
M_3	GFT: Public port infrastructure	
M_2	GFT: Other general services	
Q	Domestic production amount	Annual Statistics on Fisheries and Aquaculture Production, MAFF, Japan
QP	Domestic production value	Annual Statistics on Fisheries and Aquaculture Production, MAFF, Japan (CPI deflated)
BQP	Production value per fisherman	Annual Statistics on Movement of Fishery Enterprises; Fishery Census; and Annual Statistics on Fisheries and Aquaculture Production; MAFF, Japan (CPI deflated)
B	Number of fishermen	Annual Statistics on Movement of Fishery Enterprises; Fishery Census; MAFF, Japan
P	Price of fish	Annual Statistics on Fisheries and Aquaculture Production, MAFF, Japan
X	Number of fishing vessels	Annual Statistics of Fishing Vessels, Fisheries Agency of Japan

payment that is "aimed at reducing the costs of fixed capital and variable inputs" [1]. A major form of cost reducing transfer in Japan is the interest subsidy, which is designed to assist structural adjustment of small- to mid-sized businesses in various industrial sectors in Japan. General services are government transfers that are not necessarily paid to fishers but nevertheless reduce the costs faced by fishers [1]. This category of transfer contains a wide variety of government spending. In this paper, general service is further divided into two categories by the authors for the purpose of analyzing their effects separately:(a) construction and maintenance of public port infrastructure in fishing communities, and (b) other general services such as costs of fishery management, scientific research, and other administrative activities.

The total amount of Japan's GFTs peaked in the mid 1990s, and is declining in recent years (Fig. 1). The annual amount of direct payment (expressed as M_1) has been stable in the range of 2.0–3.8 billion Japanese yen (JPY) since its first introduction in 1981. The annual amount of the cost reducing transfer (shown as M_2) has also been stable around 2.5–4.1 billion JPY since the mid 1990s. The annual amount of the transfer related to public port infrastructures (shown as M_3) has been within the range of 190–336 billion JPY since the 1980s, whereas that of other general services (shown as M_4) was 85–110 billion JPY during the same period. All the GFT data were compiled under the OECD standard using materials from the Fisheries Agency of Japan.

Data on Japan's fisheries

Japanese fishery production showed strong growth until the early 1980s, with peak output in 1984. After that, it steadily declined. The amount and value of the current fishery production is about half of its peak (Fig. 2a, b). As for production value per fisherman, no clear trend was observed from the late 1970s to mid 1990s. It seemingly decreased after the late 1990s (Fig. 2c). The size of the workforce in the Japanese maritime fishing sector has also been consistently dwindling. The number in 2003 was less than half of that in 1971 (Fig. 2d). The average per-unit price of fishery products increased slowly until the late 1970s, peaking in 1977. In the 1980s, the average price decreased and has never recovered (Fig. 2e). The number of fishing vessels in Japan has been continuously declining over these past two decades. The total number of registered fishing vessels dropped by about 20% from 1980 to 2000 (Fig. 2f).

Methodological explanations of the cointegration analysis

A statistical test, known as cointegration analysis, is employed to examine how each of the four GFT categories relates to fishery production indicators. Because long-term
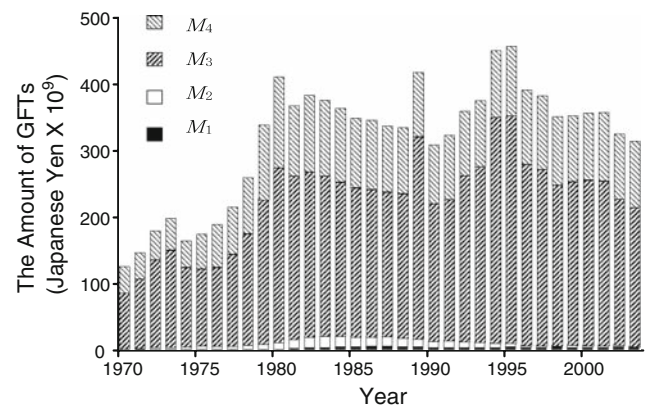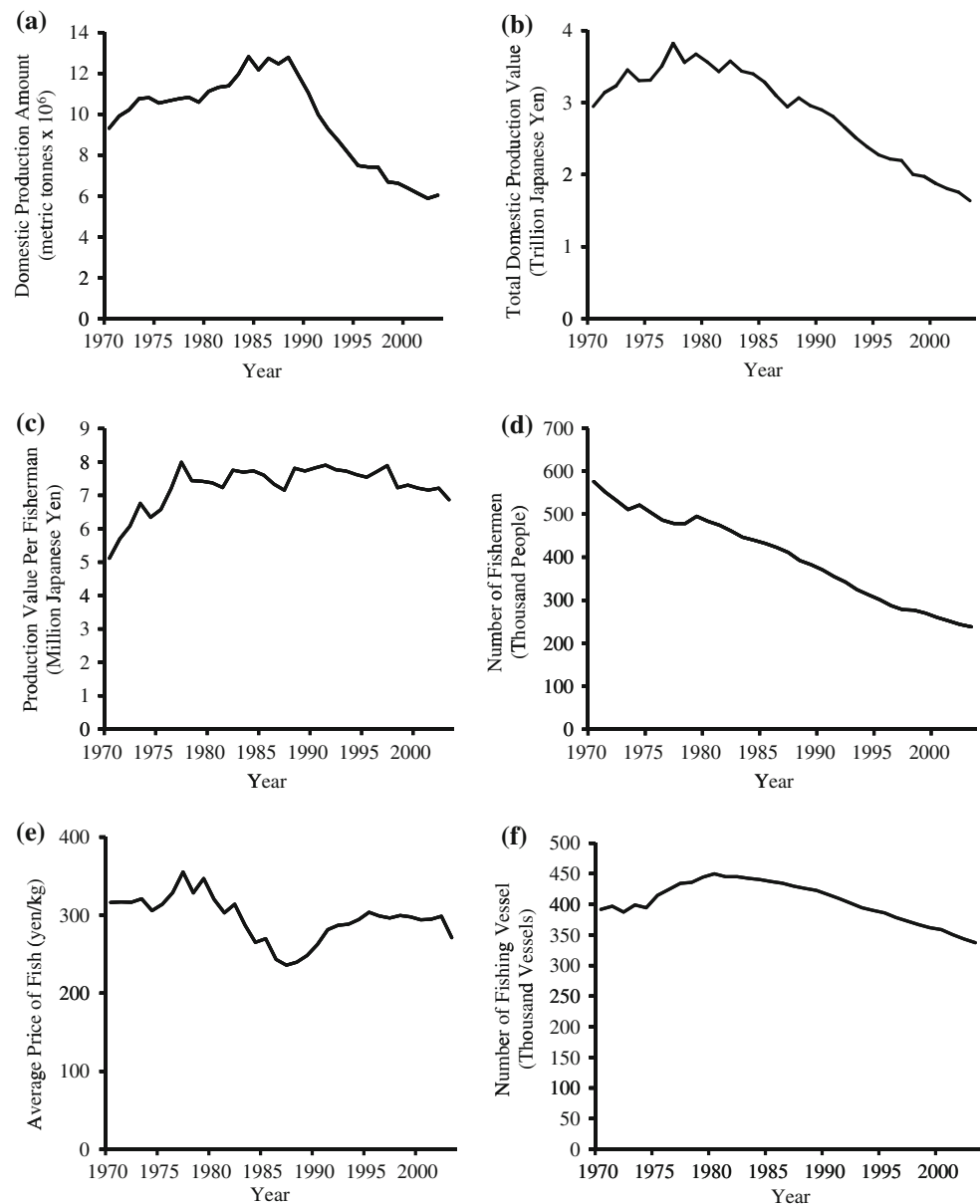

Fig. 1 Trend of Japanese GFTs to fisheries (CPI deflated)

Fig. 2 Trend of economic indicators related to Japanese fisheries. **a** Domestic production amount; (**b**) domestic production value (CPI deflated); (**c**) production value per fisherman (CPI deflated); (**d**) number of fishermen; (**e**) price of fish; and (**f**) number of fishing vessels

time-series data are used, close attention is paid to a problem known as spurious regression [3], which is characterized as follows: Regression results of time-series data may often suggest a statistically significant relationship (with high R^2 and significant t-value, for instance) where no true relationship in fact exists [4]. The main reason for this problem is a random walk in time-series data [4]. If the data constitutes a random walk, the variable can be made stationary by differencing it. If data does not constitute a random walk, the data itself is stationary and I(0). It is widely known that many macroeconomic variables can be regarded as I(1) variables. I(d) means that a variable needs to be differenced d times to make it stationary, and it is called integrated of order d.

In this study, regression analyses between variables are carried out and their errors are tested. The test between variables is expressed as follows:

$$R = a + bM_i + \varepsilon, \tag{1}$$

where R represents each variable relating to Japan's fisheries (specifically Q, QP, BQP, B, P, and X) and M_i denotes subsidies (specifically the GFTs M_1 to M_4). Since R stands for the six variables (e.g., Q, QP, BQP, B, P, and X) and M_i stands for the four variables (e.g., M_1–M_4), Eq. 1 represents 24 independent models.

Natural logarithms are taken in every variable. The equation for the estimation is now expressed as the following cointegration formula:

$$\ln R_t = \alpha_0 + \alpha_i \ln M_{it} + \varepsilon_{it} \qquad (2)$$

or

$$\varepsilon_{it} = \ln R_t - \alpha_0 - \alpha_i \ln M_{it}. \qquad (3)$$

In order to avoid errors caused by spurious regression, the error correction model (ECM) was used [5]. According to the Granger representation theorem [6], if regression of Eq. 2 has cointegration and every variable has a unit root [which means that the variable can be made approximately stationary by differencing it once: in other words the variable is integrated of order 1, or I(1)], a differenced model has a mechanism of long-term adjustment in which ε_t converges to zero. In this case, the model can be expressed as a form of ECM.

The specific expression of the ECM in this study is as follows:

$$\Delta \ln R_t = a_i \Delta \ln M_{it} - \theta \varepsilon_{t-1} + \mu_t \quad (\theta > 0), \qquad (4)$$

where the parameters a_i ($a_1 - a_4$) are unit elasticity and μ_t is a vector of white noise. Δ indicates that the variable is differenced (for instance, $\Delta \ln R_t = \ln R_t - \ln R_{t-1}$). θ is an adjustment parameter and explains adjustment speed. Accordingly, $1/\theta$ indicates the period of adjustment to equilibrium of cointegration.

The two-stage estimation method of Engle and Granger [6] is employed. The first step is the estimation of Eq. 2 above by ordinary least squares (OLS). Then, in the second step, Eq. 4 is estimated by OLS using ε_t obtained from the first-step estimation. If θ is significant, Eq. 2 has cointegration. Also, if the estimated result has cointegration and each parameter is significant in both steps, that particular variable explains the explained variable. EViews 5.1 (Quantitative Micro Software) was used as the computational software for parameter estimation.

Unit-root test

Existence of a unit root is tested to examine the order of integration of the variables prior to the estimation process. If the data constitutes a random walk, it is understood that the data has a unit root. In this analysis, Phillips-Perron test [7] is employed for unit-root test because of the length of the data. Null hypothesis H_0 is that a unit root exists in the data series, and alternative hypothesis H_1 is that the data series does not have a unit root. TSP 5.0 (TSP International) was used as the computational software for this test.

Table 2 indicates the result of the unit-root test. According to the results, it can be generally understood that every variable is I(1) and has a unit root. Thus, regression model needs to have cointegration. If it does not have cointegration, the model result is a spurious regression.

Results

The results of the cointegration test by ECM are shown in Table 3. Since ECM incorporates cointegration, the result can be real regression that demonstrates an actual relationship between variables [8].

First, it is notable that the test between M_4 (other general services) and $\ln BQP$ (production value per fisher) demonstrates a positive relationship. As for the regression result at the first step, t-values of the estimated results are satisfactory and adjusted R^2 is within a reasonable range. At the second-step regression, a value of R^2 above 0.2–0.3 can be regarded as acceptable in the case of differenced variables in general, and the actual value of adjusted R^2 for this model is in this range. The t-values of the estimated results are adequate. The result of normality test (Jarque-Bera test [9]) is satisfactory. Thus, it is considered that the regression is not a spurious regression, and the tested result of M_4 and $\ln BQP$ explains the true relationship between other general services and production value per fishermen.

The estimated parameter on second-step regression represents a per-unit effect. When M_4 increases by 1%, production value per fishermen increases by 0.20% in the same year. $1/\theta$ indicates the adjustment period, which represents the duration of the effect from the increase of M_4. This value is approximately 2.04, which means that the effect continues for 2.04 years. The value of a long-term effect can be obtained by multiplying the per-unit effect (0.20%) by the adjustment period (2.04). This value is 0.4, which suggests that production value per fishermen would increase by 0.4% in the overall period as a consequence of a 1% increase of M_4 in a given year.

Second, tested results between other GFTs (M_1–M_3) and $\ln BQP$ do not constitute meaningful outcomes. At the first level of regression analyses, adjusted R^2 have low values. The tested result at the second-step regression is not satisfactory. While the values of adjusted R^2 at the second-step regression are around 0.2–0.3, within the range of acceptable values in the case of a regression on differenced variables, t-values of the estimated parameters are not significant. Thus, the relationships between other GFTs (M_1–M_3) and $\ln BQP$ are spurious regressions, and no real relationship exists between the production value per fisherman and the three GFTs (direct payment, cost reducing transfer, and public port infrastructure).

Third, very similar results are obtained from the tests for all other remaining combination of the tested models between the GFTs and production variables ($\ln QP$, $\ln B$, $\ln Q$, $\ln P$, and $\ln X$, to be precise). All the models are spurious regressions, and therefore no relationship in fact exists between these GFTs and those variables on fishery productions.

Table 2 Results of unit-root testing (Phillips-Perron test)

Variables	Model 1		Model 2		Model 3	
	Test stat	Bandwidth	Test stat	Bandwidth	Test stat	Bandwidth
ln B	−1.03	2	1.19	1	−7.04***	2
ln BQP	−4.08**	15	−5.16***	7	0.95	1
ln M_1	−1.49	1	−1.41	0	0.02	1
ln M_2	−3.28*	3	−3.05**	3	0.59	3
ln M_3	−2.11	1	−2.80*	2	0.96	2
ln M_4	−1.51	2	−2.43	3	1.18	3
ln P	−1.85	4	−1.68	4	−0.50	4
ln Q	−1.62	3	0.15	4	−0.95	4
ln QP	−4.24**	11	2.03	2	−1.71*	4
ln X	−1.11	1	0.38	4	−0.91	4
Δln B	−4.62***	2	−4.32***	1	−2.08**	1
Δln BQP	−12.1***	21	−5.67***	3	−5.73***	3
Δln M_1	−5.41***	2	−5.40***	1	−5.31***	1
Δln M_2	−5.11***	5	−4.48***	3	−4.66***	3
Δln M_3	−5.67***	5	−5.06***	2	−5.07***	1
Δln M_4	−5.31***	2	−4.86***	3	−4.70***	3
Δln P	−5.20***	4	−5.29***	4	−5.33***	4
Δln Q	−4.39***	3	−3.73***	3	−3.52***	3
Δln QP	−7.99***	5	−5.09***	3	−4.56***	4
Δln X	−6.29***	2	−4.16***	3	−3.92***	3

Model 1 above includes constant and trend. Model 2 includes constant. Model 3 does not include constant and trend. Bandwidth is selected by Newey-West standard. * 10% significance level. ** 5% significance level. *** 1% significance level. Δ indicates that the variable is differenced

Discussion

First, the result illustrates that, out of the 24 independent tested models, only one model exhibited a true relationship between GFT and fishery production indicator. More specifically, production value per fishermen shows a positive relationship with government other general service.

The positive relationship between other general services and production value per fishermen does not come from direct price support mechanisms. This is evident from the fact that other general services cannot provide funding for any direct price supports because it does not include cost reducing transfers or direct payments, by definition.

Rather, one possible explanation is that fishery management activities which were supported by other general services may have contributed to the positive relationship. This category of financial transfer includes cost for fishery managements, scientific researches, and other administrative activities. It should be noted that fishery management mechanisms provide exclusive opportunities for a limited number of fishers with access to the fishery resources (while others are barred from resource use), and this process could have pushed up their per-capita income (as their potential rivals are unable to enter the same business and this could reduce potential competition).

Second, no other tested results between GFTs and fishery indicators show a real relationship. This can be interpreted that government financial transfers in Japan do not lead to either increase or decrease of price of fish, the total amount and the value of domestic fishery production, the number of fishermen, and the number of fishing vessels.

These outcomes are by and large reasonable judging from the current government intervention to the fishery sector in Japan. The result shows that fish price is not affected by Japan's GFT. This outcome is consistent with the situation in Japan where no price support subsidy for fishery products has been identified in its budget program throughout the period of our analysis. The other results indicate that GFTs in Japan have no real relationship with the total amount and the value of fishery production, the number of fishers, and the number of fishing vessels. Again, these results are consistent with the situation in Japan where mandatory upper limits on fishery productions (through limitation of outputs or efforts) have been imposed through fisheries licensing systems and other fisheries management measures.

Third, it can be concluded that the above result suggests that, when regulatory measures to restrict fishing productions are imposed, very limited effects are applied to fishery productions. An OECD report [1] argues that "[t]he

Table 3 Results of the cointegration tests by ECM

(a) First-step results

Explained variables	Explaining variables		Intercept	Explaining	JB	Adj R^2
ln QP	ln M_1	Estimate	15.05	−0.02	1.16	0.30
		t-stat	227.62***	−3.8****		
	ln M_2	Estimate	12.39	0.16	1.29	0.16
		t-stat	13.42***	2.66***		
	ln M_3	Estimate	21.56	−0.35	2.45	0.17
		t-stat	8.80***	−2.74***		
	ln M_4	Estimate	18.90	−0.22	2.07	0.06
		t-stat	7.92***	−1.70		
ln BQP	ln M_1	Estimate	6.53	−0.001	2.55	0.29
		t-stat	313.1***	3.72***		
	ln M_2	Estimate	5.51	0.07	0.50	0.35
		t-stat	21.66***	4.27***		
	ln M_3	Estimate	3.37	0.17	1.28	0.44
		t-stat	5.35***	5.11***		
	ln M_4	Estimate	3.18	0.19	0.16	0.60
		t-stat	6.56***	7.07***		
ln B	ln M_1	Estimate	13.12	−0.03	0.98	0.47
		t-stat	216.00***	−5.41***		
	ln M_2	Estimate	11.48	0.09	1.60	0.02
		t-stat	10.88***	1.30***		
	ln M_3	Estimate	22.80	−0.52	1.48	0.36
		t-stat	10.02***	−4.37***		
	ln M_4	Estimate	20.33	−0.41	1.23	0.23
		t-stat	8.94***	−3.29***		
ln Q	ln M_1	Estimate	16.17	−0.01	1.48	0.05
		t-stat	2111.27***	−1.65		
	ln M_2	Estimate	12.52	0.23	0.87	0.37
		t-stat	15.72***	4.46***		
	ln M_3	Estimate	20.39	−0.23	1.98	0.05
		t-stat	7.81***	−1.66		
	ln M_4	Estimate	18.25	−0.12	2.66	−0.01
		t-stat	7.43***	−0.89		

Table 3 continued

(a) First-step results

Explained variables	Explaining variables		Intercept	Explaining	JB	Adj R^2
ln P	ln M_1	Estimate	5.79	−0.01	3.10	0.47
		t-stat	251.03***	−5.44***		
	ln M_2	Estimate	6.77	−0.07	0.37	0.20
		t-stat	18.71***	−3.02***		
	ln M_3	Estimate	8.08	−0.13	2.25	0.13
		t-stat	7.98***	−2.37**		
	ln M_4	Estimate	7.56	−0.10	0.71	0.08
		t-stat	7.99***	−1.64		
ln X	ln M_1	Estimate	12.94	0.003	1.93	0.04
		t-stat	500.54***	−1.51		
	ln M_2	Estimate	11.55	0.09	1.97	0.49
		t-stat	48.02***	5.63***		
	ln M_3	Estimate	13.50	−0.03	2.08	−0.02
		t-stat	14.87***	−0.64		
	ln M_4	Estimate	12.53	0.02	3.10	−0.03
		t-stat	15.06***	0.46		

(b) Second-step results

Explained variables	Explaining variables		$-\theta$	Δ Explaining	JB	Adj R^2
Δln QP	Δln M_1	Estimate	0.01	0.00	3.48	−0.02
		t-stat	0.27	−0.03		
	Δln M_2	Estimate	0.88	−0.01	0.69	0.17
		t-stat	1.95	−0.13		
	Δln M_3	Estimate	0.01	0.03	3.49	0.01
		t-stat	0.28	0.52		
	Δln M_4	Estimate	0.03	0.11	2.22	0.19
		t-stat	0.69	1.50		

Table 3 continued

(b) Second-step results

Explained variables	Explaining variables		$-\theta$	Δ Explaining	JB	Adj R^2
$\Delta\ln BQP$	$\Delta\ln M_1$	Estimate	−0.39	0.01	2.08	0.24
		t-stat	−3.19***	0.29		
	$\Delta\ln M_2$	Estimate	−0.51	−0.14	0.77	0.39
		t-stat	−4.36***	−0.50		
	$\Delta\ln M_3$	Estimate	−0.41	0.09	4.66	0.21
		t-stat	−2.89***	1.65		
	$\Delta\ln M_4$	Estimate	−0.48	0.20	1.23	0.34
		t-stat	−3.18***	3.26***		
$\Delta\ln B$	$\Delta\ln M_1$	Estimate	−0.01	−0.001	14.80	−0.03
		t-stat	−0.43	−0.59		
	$\Delta\ln M_2$	Estimate	0.02	−0.002	17.69	0.05
		t-stat	0.64	−0.09		
	$\Delta\ln M_3$	Estimate	0.002	−0.01	27.46	−0.03
		t-stat	0.08	−0.32		
	$\Delta\ln M_4$	Estimate	0.02	−0.05	50.70	−0.02
		t-stat	0.65	−1.10		
$\Delta\ln Q$	$\Delta\ln M_1$	Estimate	0.01	0.001	1.48	−0.01
		t-stat	0.29	0.35		
	$\Delta\ln M_2$	Estimate	0.05	0.03	0.84	0.06
		t-stat	0.85	0.60		
	$\Delta\ln M_3$	Estimate	0.02	−0.003	1.64	−0.02
		t-stat	0.40	−0.05		
	$\Delta\ln M_4$	Estimate	0.03	0.01	1.71	−0.0002
		t-stat	0.78	0.09		
$\Delta\ln P$	$\Delta\ln M_1$	Estimate	−0.25	−0.004	1.89	0.13
		t-stat	−2.14**	−1.20		
	$\Delta\ln M_2$	Estimate	−0.21	0.01	0.10	0.10
		t-stat	−2.09**	0.40		
	$\Delta\ln M_3$	Estimate	−0.18	0.04	1.57	0.09
		t-stat	−1.94*	0.68		
	$\Delta\ln M_4$	Estimate	−0.23	0.15	2.29	0.24
		t-stat	−2.66**	2.13**		

Table 3 continued

(b) Second-step results

Explained variables	Explaining variables		$-\theta$	Δ Explaining	JB	Adj R^2
Δln X	Δln M_1	Estimate	0.02	−0.001	21.66	−0.02
		t-stat	0.55	−0.66		
	Δln M_2	Estimate	0.14	0.01	17.85	0.25
		t-stat	2.09**	0.46		
	Δln M_3	Estimate	0.03	0.02	35.03	0.06
		t-stat	0.84	0.99		
	Δln M_4	Estimate	0.05	0.08	13.89	0.49
		t-stat	1.53	3.51***		

The Engle and Granger two-step regression method was adopted. * 10% significance level. ** 5% significance level. *** 1% significance level. Δ indicates that the variable is differenced

extent to which fisheries in OECD countries are effectively managed is therefore critical to determining the effect of (government financial) transfers." Although further scrutiny is awaited, this study could provide empirical support for an argument that, under an effective fishing management system, fisheries subsidies do not necessarily cause production increases or negative impact on fishing stocks. For more concrete confirmation of this point, extension of the scope of this analysis to cover longer time periods (including data from the 1950s and 1960s, for instance) is awaited.

Lastly, the focus of this study is placed on the identification of statistical relationship between subsidies and fishery production. It would be useful if additional study is conducted to identify what other factors, other than subsidies, are affecting fishery productions. The results of such studies could facilitate further understanding of the role of fisheries subsidies.

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