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National income and fishery consumption: a global investigation

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We apply the panel unit root tests, heterogeneous panel co-integration analysis, and panel-based error correction models (ECM) to examine the long-term co-integrated relationship between national income and fishery consumption in a panel of 101 countries for the period 1970–2006. In addition, we utilise a panel dynamic ordinary least squares (DOLS) model, to assess the effect of national income on fish consumption, and vice versa. Our empirical results provide clear support for a positive long-term co-integrated relationship between national income and fishery consumption after allowing for a heterogeneous country effect. Further, we display a bi-directional causality among these variables via the dynamic panel-based ECM in the long-term, and demonstrate that fish is a common food. Finally, our full sample is divided into developed, developing, southern hemisphere countries (SHC) and northern hemisphere countries (NHC) to discover the broader effect of income on fish consumption if any, and vice versa, among different levels of economic development and diverse regions. This facilitates our understanding and provides more insight into the characteristic of fishery among different levels of economic–geography conditions. We propose fishery policy recommendations through our findings.

Keywords: fish consumption; economic growth; panel co-integration; causality

JEL classification: C22; C33; O47; Q22

1. Introduction

Global average fishery and seafood consumption per capita has reached 16.69 kg in 2008 (live fish weight equivalent), an increase of 24% from 1990.[1] According to Nestle et al. (1998), annual household income influences food choices, particularly costly foods such as fish. Namely, fish is expected to be less accessible in ‘poor urban and rural communities’, and even if it is available, insufficient capital potentially generates a barrier for acquisition and consumption (Nestle et al., 1998). Indeed, Trondsen et al. (2003) show that those with the highest income had significantly lower likelihood of perceiving price as a barrier to the consumption of fish. Households that maximise utility, subject to price and income, recognise the ‘prevailing price’ as a motivation for not consuming more (Myrland et al., 2000). Previous literature has investigated the relationship between household income and fishery consumption. However, these findings are based on individual country analysis and generally do not account for causal impact between fishery consumption and income.

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The panel data approach provides more powerful tests and estimates, and allows us to increase the information available from the cross-sections. The purpose of this article is to examine the long run co-movement and the causal relationship between national income (measured by real gross domestic product [GDP] per capita) and fishery consumption (measured by the annual food supply of fish and fishery products per capita) by working with 37-year panel data covering the period of 1970–2006 for 101 countries.[2] For a deeper investigation, we divide our full sample into 24 developed countries (DDC) and 77 developing countries (DGC), and also group our full sample into 73 northern hemisphere countries (NHC) and 18 southern hemisphere countries (SHC). We attempt to discover, if any, the broader effect between GDP and fishery, among different levels of economic development and different regions. It is expected that the empirical results will lead to different policy implications and provide different recommendations for all regions in our analysis.

As a result of this continued interest in food behaviour, several studies have attempted to identify the effect of income on fishery consumption via a cross-sectional analysis (Myrland et al., 2000; Trondsen et al., 2003, 2004; Verbeke & Vackier, 2005). However, these empirical studies have not resolved the question of how fish consumption is influenced by income. For instance, Myrland et al. (2000) and Trondsen et al. (2003) demonstrate that there is no direct relationship between income and fishery consumption in Norway. In contrast, Burger (2002) finds that consumption patterns of fish were negatively correlated with mean income in the Newark Bay Complex. Trondsen et al. (2004) discover that income has a significant negative association with consumption of lean and processed fish in Norway. Conversely, Verbeke and Vackier (2005) show that fish consumption is considerably lower among the lowest income group in Belgium.

A similar body of research has been devoted to understanding the broader macroeconomic impacts of fish consumption (Gillett & Lightfoot, 2002; Peterson, 2003; Zeller et al., 2005; Bell et al., 2009; Kim, 2010). Petersen (2003) emphasises the significance of the fishery industry and underscores that fishery revenue represents a sizeable amount of government revenue, export earnings and GDP of the Pacific island countries.[3] In addition to providing food and trade, Zeller et al. (2005) highlights the 'subsistence, social, and cultural' value of fish for many Pacific island economies. Bell et al. (2009) indicates that fish is the most critical renewable resource and supplies extensively to 'subsistence and market-based economies' in Pacific island countries and territories. Gillett and Lightfoot (2002) document in great detail the importance of fishing and fisheries to the economies of Pacific island countries. Meanwhile, the expansion of fishery industries has generated increasing opportunities for employment, thereby inducing economic development (Kim, 2010). In considering the relationship between fish consumption and aggregate income, we are particularly motivated by Kim (2010), who emphasises that fish consumption has substantially increased as the overall economic conditions have improved in northeastern Asia.

Fish consumption has been continually recommended as an important part of a healthy diet and good nutrition. It has been maintained that consuming a mixture of fish and seafood prevents helps to prevent various diseases (Trondsen et al., 2004). Perhaps it is not surprising that nutritionists and physicians advocate the consumption of fish and fishery products. Altekruse et al. (1995) and Trondsen et al. (2004) explain the presence of a positive relationship between fish consumption and health consciousness. Connor and Connor (2000) argue that high consumption of fish oil lessens the probability of various diseases. Given the implications and importance of fish and fishery products, it is critically important to understand the relationship between fish consumption and national income.

Therefore, we ask, what is the long-term relationship between national income and fishery consumption? What are the differences among different levels of economic–geography conditions? More importantly, how can economic growth contribute to an increase in fishery consumption? Employing panel data analysis enables us to account for the presence of heterogeneity in the estimated parameters and dynamics across countries (Baltagi, 1995). Hence, different from time-series or traditional panel data analysis, the panel co-integration model can selectively pool the long-term information contained in the panel error correction model (ECM) while allowing the short-term dynamics and fixed effects to be heterogeneous among different countries within the panel (Pedroni, 2000). In addition, the panel co-integration technique provides more precise point estimates of the co-integration vector with reasonably accurate asymptotic approximations to the exact sampling distribution (Mark & Sul, 2003).

Hence, we apply panel unit root and heterogeneous panel co-integration tests to investigate the long-term co-integrated relationship between GDP and fishery. Then, after the long-term relationship is established, we utilise a panel dynamic ordinary least squares (DOLS) model, with asymptotically unbiased estimators, to assess the influence of GDP on fishery, and vice versa. Further, we generate a panel ECM to explore the short-term and long-term causalities between income and fish consumption. Using the empirical results, we argue that an uni-directional causality flowing from income to fishery consumption indicates that fish is a common food, for which demand increases as income rises and decreases as income falls, i.e. positive income elasticity (under the assumption that prices remain constant). Alternatively, a bi-directional causality suggests that fishery consumption and the level of income mutually influence each other endogenously. Also, a uni-directional causality flowing from fish consumption to income provides evidence that the development of fishery industry generates economic growth, as argued by Kim (2010), for example. Further, the lack of causality implies zero income elasticity, for which demand does not change as income changes.

The rest of the article is structured as follows. In Section 2, we explain the empirical methodology utilised in our investigation. Section 3 describes the variables, provides data analysis and discusses the empirical results. The final section summarises the major findings and provides policy recommendations.

2. Empirical methodology

2.1. Panel unit root tests

Prior to examining the co-integrated relationship among the variables and implementing the panel data approach, we confirm that all the variables follow the integrated of order one, I (1) process. We employ the panel unit root tests proposed by Levin et al. (2002) to investigate the stationarity of the variables. These tests provide relevant information for determining the characteristics of non-stationarity of the panel. Levin et al. (2002) proposed a panel-based augmented Dicky and Fuller (1979) test that restricts parameters by keeping them identical across cross-sectional regions as follows:

$$\Delta y_{it} = \theta\alpha_i + \boldsymbol{\vartheta}_i y_{it-1} + \sum_{j=1}^{k} \theta_j \Delta y_{it-j} + e_{it}, \tag{1}$$

where $t = 1, ..., T$ time periods and $i = 1, ...N$ members of the panel. The Levin et al. (2002) tests the null hypothesis of $\boldsymbol{\vartheta}_i = \boldsymbol{\vartheta} = 0$ for all i, against the alternative of $\boldsymbol{\vartheta}_1 = \boldsymbol{\vartheta}_2 ... = \boldsymbol{\vartheta} < 0$ for all i, with the tests based on the statistics $t_{\vartheta} = \hat{\boldsymbol{\vartheta}}/s.e.(\hat{\boldsymbol{\vartheta}})$.

Nevertheless, a shortcoming of the Levin et al. (2002) test is that ϑ is restricted, provided that it is kept identical across regions under both the null and alternative hypotheses.

Subsequently, Im et al. (2003) relaxed the assumption of the identical first-order autoregressive coefficients of the Levin et al. (2002) test and allowed ϑ to vary across regions under the alternative hypothesis. Im et al. (2003) tests the null of $\vartheta_i = 0$ for all i, and the alternates of $\vartheta_i < 0$ for all i. According to the mean-group approach, the Im et al. (2003) test uses the average of the t_{ϑ_i} statistics to conduct the following $\bar{Z}$ statistic:

$$\bar{Z} = \sqrt{N}(\bar{t} - E(\bar{t}))/\sqrt{Var(\bar{t})}, \tag{2}$$

where $\bar{t} = (1/N)\sum_{i=1}^{N} t_{\vartheta_i}$; the terms $E(\bar{t})$ and $Var(\bar{t})$ are the mean and variance of each t_{ϑ_i} statistic respectively, and they are produced by simulations and are tabulated in Im et al. (2003). Also, $\bar{Z}$ converges to a standard normal distribution. Based on Monte Carlo simulation results, the Im et al. (2003) test demonstrated that the test has more favourable finite sample properties than the Levin et al. (2002) test. In the interest of robustness, we present the Im et al. (2003) and Levin et al. (2002) panel unit root tests in the empirical results.

2.2. The panel co-integration tests

We utilise the panel co-integration test, developed by Pedroni (2004), to explore the long-term relationship between fishery and GDP. Pedroni (2004) considers the following time series panel regression:

$$Y_{it} = \alpha_i + \delta_i t + X_{it}\beta_i + e_{it} \tag{3}$$

where Y_{it} and X_{it} are the observable variables ('fishery' and GDP, respectively) with dimension of $(N * T) \times 1$ and $(N * T) \times m$, respectively. The parameters α_i and δ_i allow for the possibility of member specific fixed effects and deterministic trends, respectively. The slope coefficients β_i are also permitted to vary by individual, so that in general the co-integrating vectors may be heterogeneous across members of the panel (Pedroni, 2004). Pedroni (1999) developed asymptotic and finite-sample properties of testing statistics to examine the null hypothesis of non-co-integration in the panel. The tests allow for heterogeneity among individual members of the panel, including heterogeneity in both the long-term co-integrating vectors and in the dynamics, given that there is no reason to believe that all parameters are the same across countries.

Two types of tests are suggested by Pedroni (2004). The first type is based on the within-dimension approach, which includes four statistics. They are panel v-statistic, panel ρ-statistic, panel PP-statistic, and panel augmented Dickey–Fuller test (ADF)-statistic. These statistics pool the autoregressive coefficients across different members for the unit root tests on the estimated residuals. The second test by Pedroni (2004) is based on the between-dimension approach, which includes three statistics. They are group ρ-statistic, group PP-statistic, and group ADF-statistic. These statistics are based on estimators that simply average the individually-estimated coefficients for each member.[4] Each of these tests is able to accommodate individual specific short-term dynamics, individual specific fixed effects and deterministic trends, as well as individual specific slope coefficients (Pedroni, 2004).

All seven tests are distributed as being standard normal asymptotically. This requires standardisation based on the moments of the underlying Brownian motion function. The panel v-statistic is a one-sided test where large positive values reject the null of no co-integration. The remaining statistics diverge to negative infinitely, which means that large negative values reject the null. The critical values are also tabulated by Pedroni (2004).

2.3. Panel dynamic ordinary least squares estimations

In the presence of unit root variables, the effect of superconsistency may not dominate the endogeneity effect of the regressors if DOLS is employed. In order to investigate the panel co-integrated relationship between fishery and GDP, we implement the panel DOLS model, provided by Kao and Chiang (2000), which includes leads and lags of the independent variables as shown in the following equations:

$$FISHERY_{i,t} = \varphi_i + \phi_i GDP_{i,t} + \sum_{j=-q_i}^{q_i} \delta_{ij} \Delta GDP_{i,t+j} + v_{i,t}, \tag{4}$$

$$GDP_{i,t} = \alpha_i + \beta_i FISHERY_{i,t} + \sum_{j=-q_i}^{q_i} \gamma_{ij} \Delta FISHERY_{i,t+j} + v_{i,t}, \tag{5}$$

where $t = 1, \ldots, T$ $i = 1, \ldots, N$, α_i and φ_i indicate the country-specific effect, and q_i represents the leads and lags of the independent variable in first differences. $v_{i,t}$ denotes the disturbance terms following the I(0) process. The panel DOLS estimation is fully parametric and offers a computationally convenient alternative to the panel fully modified OLS (FMOLS) estimator proposed by Phillips and Moon (1999) and Pedroni (2004).

The co-integration analysis of the panel data consists of four steps. First, we use the Levin et al. (2002) and Im et al. (2003) tests to determine the characteristics of non-stationarity of the panel. Second, we employ the Pedroni (2004) heterogeneous panel co-integration test to investigate the long-term relationship between GDP and fishery. Third, after the long-term relationship is established, we utilise the panel DOLS technique for heterogeneous co-integrated panels to estimate long-term equations. Finally, we produce a panel ECM to explore the short-term and long-term causalities between two variables.

3. Empirical results

3.1. The analysis of full sample

We utilise annual data, over the 1970–2006 period, covering 101 countries.[5] The annual data is utilised in order to circumvent any complications that could arise from seasonality, provided that fishery policy considers seasonality in fishery demand (Vanegas & Croes, 2003). We extract annual food supply of fish and fishery products per capita (unit: kg/person) from the FAO of the United Nations.[6] The series real GDP per capita (constant 2000 prices), expressed in US dollars, is taken from the World Development Indicators (WDI) (2008). The time series fishery and GDP are transformed in natural logarithms. We provide descriptive statistics in Table 1. In addition, time series behaviours of variables for each country plot as for each country in Figures 1 and 2, respectively. We also provide some preliminary evidence of potential long-term relationships between mean of GDP and fishery in Figure 3, illustrating a trend of long-term co-movement between the variables.

Table 2 presents the panel unit root results for each of the series. According to Levin et al. (2002) and Im et al. (2003) test statistics, the variables 'fishery' and GDP

Table 1. Descriptive Statistics: Real GDP and fishery consumption per capita.

Countries	GDP	FISHERY	Countries	GDP	FISHERY
Algeria	7.49	3.36	Kiribati	6.36	69.71
Argentina	8.86	6.93	Lesotho	5.83	0.52
Australia	9.71	18.14	Liberia	5.74	10.39
Austria	9.81	8.64	Madagascar	5.63	7.11
Bangladesh	5.60	9.18	Malawi	4.96	8.14
Belize	7.72	9.58	Malaysia	7.78	45.66
Benin	5.68	11.08	Mali	5.45	8.58
Bolivia	6.89	1.56	Malta	8.62	20.30
Botswana	7.51	3.17	Mauritania	6.09	13.43
Brazil	8.10	6.43	Mexico	8.51	9.19
Burkina Faso	5.21	1.69	Morocco	7.03	6.84
Burundi	4.85	2.92	Nepal	5.16	0.69
Cameroon	6.50	11.39	Netherlands	9.81	14.67
Canada	9.83	21.70	New Zealand	9.39	20.03
Central African	5.64	4.96	Nicaragua	6.81	1.78
Chad	5.23	4.77	Niger	5.33	1.08
Chile	8.06	18.46	Nigeria	5.95	8.65
China	5.93	13.21	Norway	10.19	45.55
Colombia	7.46	3.90	Pakistan	6.02	1.83
Congo	6.93	26.08	Panama	8.13	12.77
Costa Rica	8.09	5.69	Paraguay	7.15	2.94
Côte d'Ivoire	6.60	16.46	Peru	7.64	19.66
D. R. Congo	5.18	7.41	Philippines	6.82	32.65
Denmark	10.05	22.12	Portugal	8.94	51.70
Dominican Republic	7.39	7.48	South Korea	8.61	44.57
Ecuador	7.16	7.78	Rwanda	5.48	0.53
Egypt	6.95	7.91	St. Vincent	7.56	13.62
El Salvador	7.56	2.63	Saudi Arabia	9.27	6.81
Fiji	7.52	31.33	Senegal	6.14	26.07
Finland	9.79	30.00	Seychelles	8.52	59.06
France	9.79	28.02	Sierra Leone	5.46	18.59
Gabon	8.47	39.51	Solomon Islands	6.52	47.09
Gambia	5.71	19.46	South Africa	8.07	8.63
Germany	9.79	12.77	Spain	9.27	37.09
Ghana	5.45	27.22	Sri Lanka	6.34	16.31
Greece	9.34	18.97	Sudan	5.74	1.38
Guatemala	7.34	1.04	Swaziland	7.01	2.00
Guinea-Bissau	5.12	3.42	Sweden	10.00	27.39
Guyana	6.69	39.99	Switzerland	10.31	12.13
Haiti	6.36	2.70	Syria	6.92	1.41
Honduras	6.80	2.03	Togo	5.61	10.29
Iceland	10.09	87.28	Trinidad and Tobago	8.67	12.62
India	5.74	3.74			
Indonesia	6.27	15.41	Tunisia	7.31	9.11
Iran	7.37	3.33	Turkey	7.76	6.42
Ireland	9.52	16.11	United Kingdom	9.83	18.55
Israel	9.58	19.35	United States	10.19	19.32
Italy	9.60	18.86	Uruguay	8.54	5.81
Jamaica	7.96	22.60	Venezuela	8.58	14.15
Japan	10.26	66.84	Zambia	5.99	9.35
Kenya	6.02	4.35	Zimbabwe	6.39	2.05

Source: Author calculation.

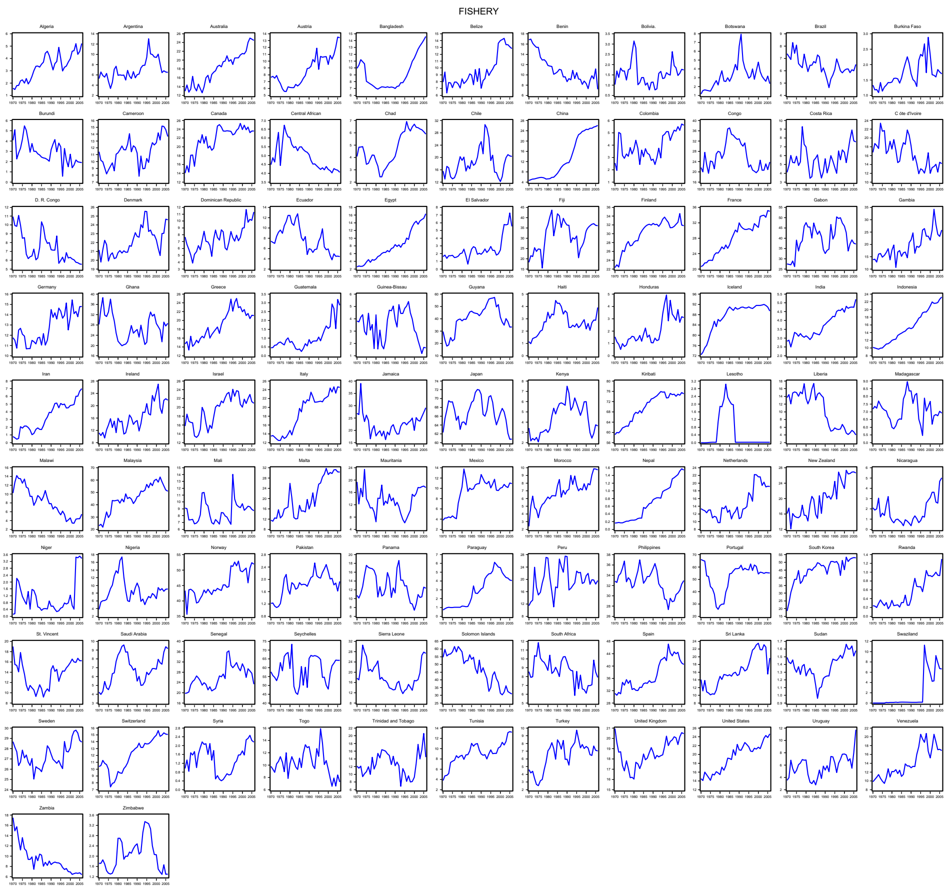

Figure 1. Plots of fishery consumption per capita (kg/capita).
Source: Author calculation.

exhibit unit root behaviour at the 5% significance level at least. In addition, the results display the stationarity of the differencing variables, indicating that the variables in the level form follow I (1) process. Next, we proceed to investigate the co-integrated relationship between GDP and fishery. We implement the following equations:

$$FISHERY_{it} = \phi_i + \gamma_i t + \chi_i GDP_{it} + v_{it} \tag{6}$$

$$GDP_{it} = \alpha_i + \delta_i t + \beta_i FISHERY_{it} + \varepsilon_{it} \tag{7}$$

Table 3 reports the estimation results of the panel co-integration tests. When the dependent variable is 'fishery' (column 2), all test statistics significantly reject the null of no co-integration, providing strong evidence for a co-integrated relationship among the variables. Also, when the dependent variable is GDP (column 3), four test statistics (panel ρ, panel PP, panel ADF, and group PP) significantly reject the null of no co-integration. Therefore, our findings establish a long-term co-integrated relationship between fishery and GDP. Further, we apply panel DOLS estimation, with asymptotically unbiased estimators, to examine the long-term effect of fishery on GDP, and vice versa.

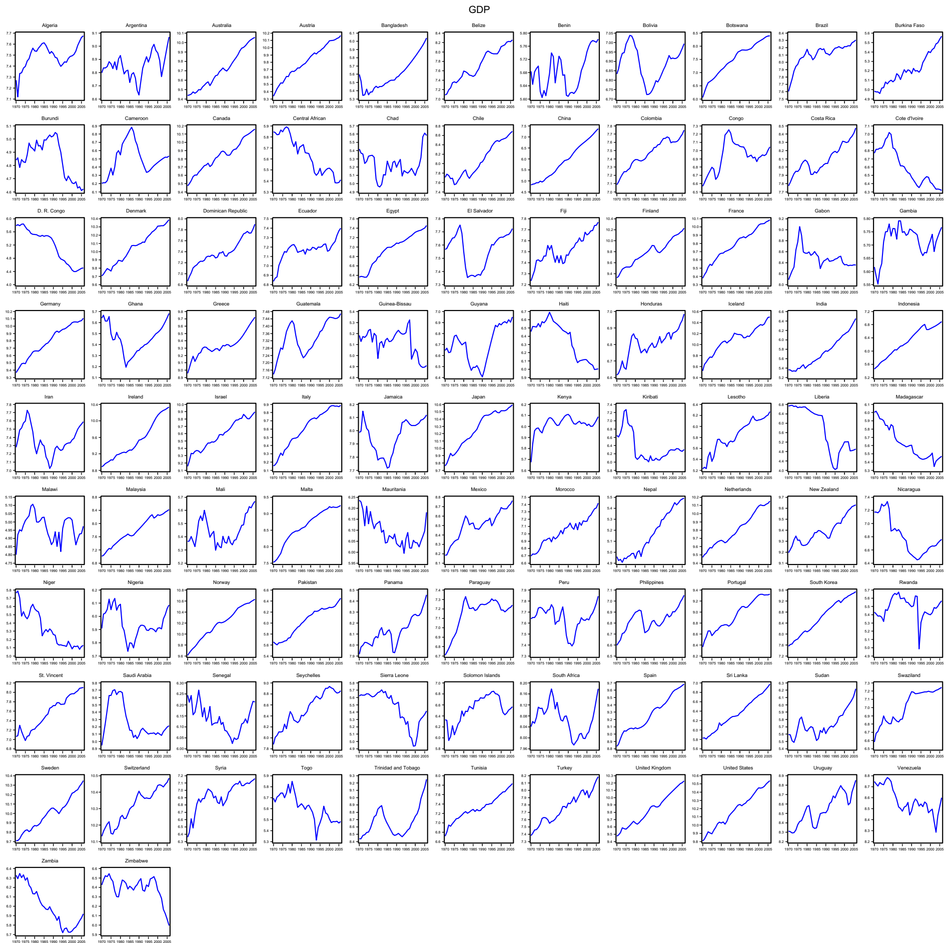

Figure 2. Plots of GDP per capita.
Source: Author calculation.

Table 4 reports the results of country-by-country and panel DOLS, when the dependent variable is 'fishery'. On a per country basis, 61 out of 101 countries in our sample demonstrate that GDP has a positive impact on fishery, where the statistical significance is marginal at least at 10% level. The panel estimator is displayed at the bottom of Table 4 (5.712), these results are in line with Kim (2010) who explains that fishery consumption has considerably increased as the overall economic conditions have improved in northeastern Asia. The DOLS estimates of the elasticity of GDP with respect to fishery are significantly larger than 1 in over half the countries in our sample. Further, we find that the variable GDP is negative and statistically significant in Lesotho, Panama, the Philippines, Rwanda, Senegal, the Solomon Islands and Venezuela. These findings are consistent with Trondsen et al. (2004), who discover that income has a significant negative association with consumption of lean and processed fish in Norway.

Next, we present the results of country-by-country and panel DOLS, when the dependent variable is GDP in Table 5. Again, the panel estimator is displayed at the bottom of Table 5 as 0.077, the variable 'fishery' is positive and statistically significant

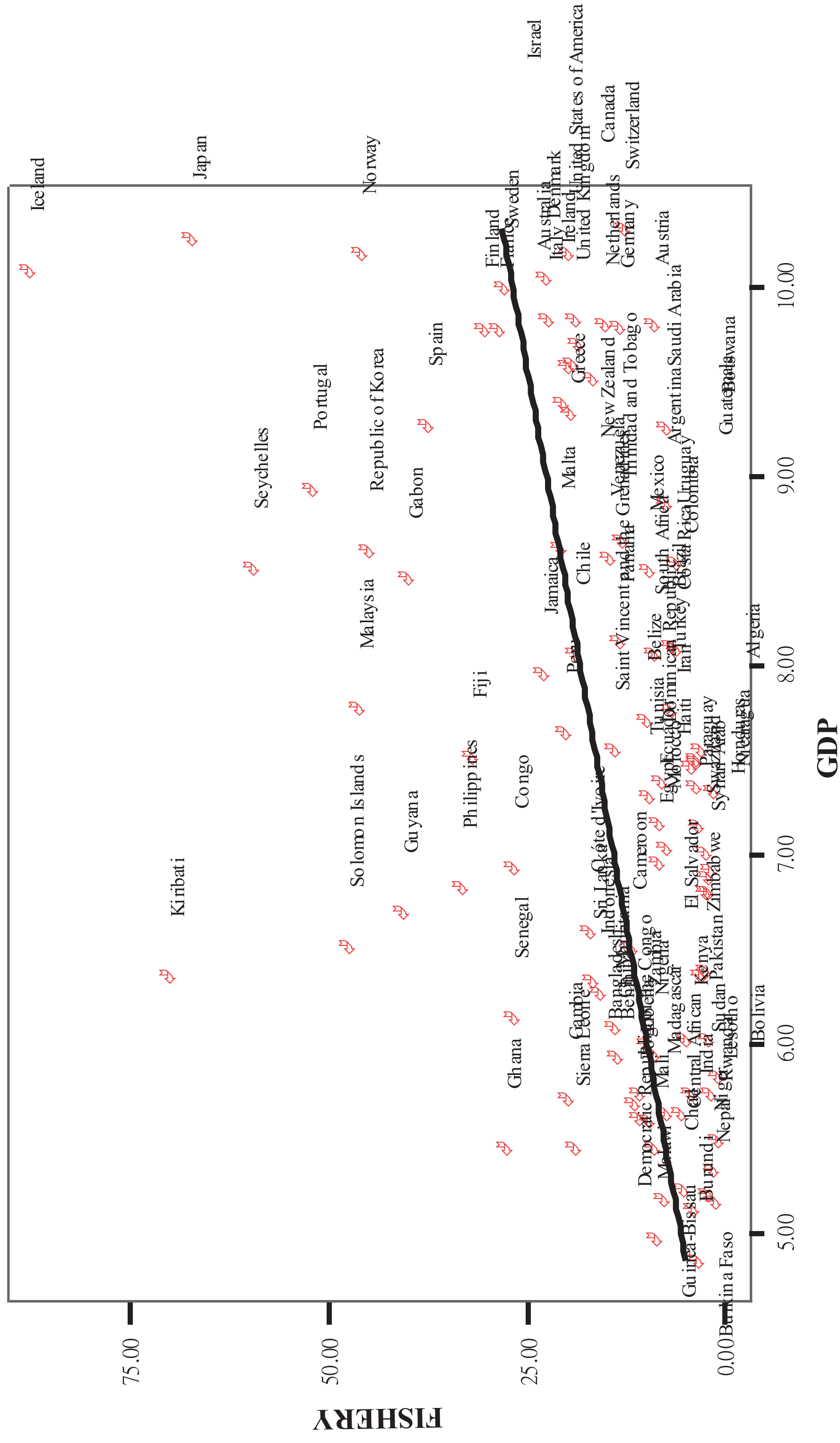

Figure 3. Plot of fishery and GDP.
Source: Author calculation.

Table 2. Panel unit root tests.

	Levin et al. (2002)	Im et al. (2003)
Level		
Fishery	−0.188	0.949
GDP	−0.616	−0.666
First-difference		
Fishery	−2.573**	−1.676**
GDP	−17.800**	−19.773**

Note: All variables are in natural logarithms.
** indicates statistical significance at the 5% level.
Source: Author calculation.

Table 3. Panel co-integration test.

Dependent variables	Dependent Variable is FISHERY	Dependent Variable is GDP
Panel variance	4.802**	−2.934
Panel ρ	−7.397**	−1.556*
Panel PP	−7.754**	−3.757**
Panel ADF	−6.031**	−2.182**
Group ρ	−6.447**	0.705
Group PP	−8.726**	−2.664**
Group ADF	−6.431**	−0.825

Note: Statistics are asymptotically distributed as normal. The variance ratio test is right-sided, while the others are left-sided.
**(*) rejects the null of no co-integration at the 5% (10%) level.
Source: Author calculation.

at the 5% level. Compared with Table 4, the magnitude of GDP is larger than fishery, highlighting the role of income for fishery consumptions. On a per country basis, 66 out of 101 countries in our sample demonstrate that fishery has a positive effect on GDP, where the statistical significance is marginal at least at 10% level. Our findings are consistent with Gillett and Lightfoot (2002), who emphasise the importance of fishing and fisheries to the economies of Pacific island countries. In addition, Bell et al. (2009) argues that fish is the most fundamental renewable resource and supplies extensively to the economies in Pacific island countries and territories. Further, Kim (2010) explains that the development of fishery industries has produced increasing opportunities for employment, thereby stimulating economic development. Also, we display that the variable 'fishery' is negative and statistically significant at the 5% level in Kiribati, Panama, the Philippines, Rwanda, Senegal, the Solomon Islands and Venezuela. We provide a detailed summary of these results in Table 6. To conclude, the country-by-country and panel co-integration test results clearly indicate that there is a considerably strong long-term co-integrated relationship between fishery and GDP in our sample.

Once the two variables are co-integrated, we follow Chang and Lee (2010), to implement a panel ECM to examine the short- and long-term causalities between GDP and fishery.[7] A panel-based ECM accounts for the two-step procedure from Engle and Granger (1987): the first step is the estimation of the long-term model for equations (6) and (7) in order to obtain the estimated residuals, ε_{it} and v_{it} (error correction term [EC]), and the second step is to estimate the Granger causality model with a dynamic error correction as follows:

Table 4. Panel DOLS estimates tests of co-integration (dependent variable: fishery).

Countries	Coefficient	t-statistics	Countries	Coefficient	t-statistics
Algeria	5.977**	2.086	Kiribati	−13.149**	−3.805
Argentina	17.624**	2.497	Lesotho	−2.426**	−2.987
Australia	19.041**	10.824	Liberia	5.099**	12.987
Austria	10.468**	7.668	Madagascar	0.500	0.324
Bangladesh	13.886**	3.592	Malawi	19.171	1.019
Belize	6.102**	4.447	Malaysia	22.342**	14.417
Benin	−18.349	−1.118	Mali	9.005*	1.821
Bolivia.	3.727**	4.805	Malta	14.239**	2.734
Botswana	0.952	1.239	Mauritania	21.978	1.068
Brazil	−2.359	−1.407	Mexico	14.670**	3.624
Burkina Faso	1.448**	2.211	Morocco	8.254	10.497
Burundi	2.265	1.034	Nepal	2.315**	22.119
Cameroon	3.760	0.878	Netherlands	17.834**	5.573
Canada	12.318**	7.649	New Zealand	35.765**	11.564
Central African	4.527**	18.204	Nicaragua	0.536	0.585
Chad	4.323	0.702	Niger	0.389	0.383
Chile	−1.908	−0.790	Nigeria	6.537	0.875
China	11.662**	13.851	Norway	16.763**	11.045
Colombia	2.435	1.476	Pakistan	0.939**	4.823
Congo	27.987**	3.004	Panama	−24.018**	−7.183
Costa Rica	4.212**	2.279	Paraguay	5.175	1.072
Côte d'Ivoire	11.112**	3.773	Peru	−4.034	−0.650
D. R. Congo	1.417**	2.799	Philippines	−23.390**	−3.294
Denmark	4.592**	2.432	Portugal	34.213**	5.232
Dominican Republic	6.943**	11.645	South Korea	7.978**	8.337
Ecuador	−17.600	−1.418	Rwanda	−1.727**	−1.997
Egypt	13.529**	7.050	St. Vincent	4.521**	4.839
El Salvador	3.702	1.281	Saudi Arabia	1.472	1.058
Fiji	9.232	0.592	Senegal	−47.533**	−2.822
Finland	11.270**	7.262	Seychelles	2.072	0.303
France	22.355**	12.816	Sierra Leone	9.254**	2.017
Gabon	4.221	0.377	Solomon Islands	−26.172**	−4.089
Gambia	−51.472	−1.239	South Africa	15.982**	2.449
Germany	5.680**	3.995	Spain	20.196**	6.636
Ghana	28.301**	3.335	Sri Lanka	13.819**	17.347
Greece	19.870**	3.026	Sudan	0.868**	4.278
Guatemala	7.498**	5.758	Swaziland	10.567**	2.482
Guinea-Bissau	11.202**	3.532	Sweden	5.346**	3.807
Guyana	−15.286	−0.746	Switzerland	24.698**	17.956
Haiti	1.414	1.356	Syria	1.456	0.824
Honduras	13.745**	3.730	Togo	−1.054	−0.216
Iceland	17.706**	9.091	Trinidad and Tobago	17.631**	6.096
India	2.629**	8.169	Tunisia	5.020**	5.172
Indonesia	9.121**	13.291	Turkey	6.242**	2.548
Iran	−3.498	−1.195	United Kingdom	4.868**	9.831
Ireland	7.281**	6.470	United States	14.531**	8.114
Israel	17.222**	11.647	Uruguay	6.433**	3.307
Italy	21.028**	8.271	Venezuela	−22.865**	−2.804
Jamaica	17.006**	6.095	Zambia	6.783**	5.983
Japan	3.476	1.098	Zimbabwe	−1.277	−0.499
Kenya	15.327	1.544	***Panel***	***5.712****	***41.371***

Notes: t-statistics in parenthesis. Asymptotic distribution of t statistic is standard normal as T and N go to infinity.
**(*) indicates the statistical significance at 5% (10%) level. All results allow for up to five structural breaks for each state.
Source: Author calculation.

Table 5. Panel DOLS estimates tests of co-integration (dependent variable: GDP).

Countries	Coefficient	t-statistics	Countries	Coefficient	t-statistics
Algeria	0.038*	1.788	Kiribati	−0.075**	−5.736
Argentina	0.030**	2.604	Lesotho	−0.138	−1.339
Australia	0.054**	12.273	Liberia	0.193**	8.988
Austria	0.083**	8.163	Madagascar	−0.041	−0.362
Bangladesh	0.042**	7.155	Malawi	0.010	1.454
Belize	0.119**	4.226	Malaysia	0.041**	12.472
Benin	−0.002	−0.224	Mali	0.047*	1.656
Bolivia.	0.225**	7.270	Malta	0.060**	4.867
Botswana	0.358**	3.045	Mauritania	0.005	0.833
Brazil	−0.120**	−3.882	Mexico	0.037**	2.985
Burkina Faso	0.336**	5.649	Morocco	0.108**	9.646
Burundi	0.086	1.470	Nepal	0.444**	22.097
Cameroon	0.045	1.191	Netherlands	0.048**	6.855
Canada	0.060**	5.447	New Zealand	0.025**	9.441
Central African	0.204**	19.567	Nicaragua	0.125	1.452
Chad	0.019	0.796	Niger	0.190*	1.888
Chile	0.025	0.635	Nigeria	0.006	0.695
China	0.091**	12.919	Norway	0.063**	8.838
Colombia	0.090**	1.984	Pakistan	0.721**	6.232
Congo	0.024**	3.219	Panama	−0.043**	−5.977
Costa Rica	0.094*	1.645	Paraguay	0.043**	2.615
Côte d'Ivoire	0.071**	3.738	Peru	−0.019	−1.234
D. R. Congo	0.377**	4.184	Philippines	−0.024**	−3.365
Denmark	0.114**	4.433	Portugal	0.023**	4.006
Dominican Republic	0.141**	8.075	South Korea	0.106**	4.927
Ecuador	−0.009	−1.400	Rwanda	−0.235**	−2.011
Egypt	0.077**	6.012	St. Vincent	0.080**	3.810
El Salvador	0.013	0.168	Saudi Arabia	−0.034	−0.544
Fiji	0.000	−0.038	Senegal	−0.010**	−3.126
Finland	0.062**	4.219	Seychelles	0.007	0.282
France	0.043	17.753	Sierra Leone	0.032**	2.674
Gabon	−0.007	−1.051	Solomon Islands	−0.012**	−2.027
Gambia	−0.002	−0.761	South Africa	0.029**	2.354
Germany	0.133**	7.445	Spain	0.045**	9.362
Ghana	0.025**	5.185	Sri Lanka	0.077**	22.144
Greece	0.027**	4.722	Sudan	0.826**	6.362
Guatemala	0.138**	3.643	Swaziland	0.039**	2.201
Guinea−Bissau	0.074**	3.241	Sweden	0.100**	2.845
Guyana	−0.006	−0.954	Switzerland	0.038**	22.048
Haiti	0.080	0.762	Syria	0.068	0.801
Honduras	0.046**	4.059	Togo	−0.021	−0.664
Iceland	0.027**	2.041	Trinidad and Tobago	0.020**	2.510
India	0.429**	16.385	Tunisia	0.128**	4.860
Indonesia	0.085**	10.491	Turkey	0.085**	3.338
Iran	−0.018	−0.550	United Kingdom	0.157**	11.156
Ireland	0.114**	15.031	United States	0.063**	9.350
Israel	0.056**	7.907	Uruguay	0.096**	3.592
Italy	0.049**	13.777	Venezuela	−0.026**	−2.803
Jamaica	0.043**	5.883	Zambia	0.101**	5.297
Japan	0.020	0.458	Zimbabwe	0.056	1.182
Kenya	0.020**	4.137	***Panel***	***0.077****	***44.265***

Notes: Same as Table 4.
Source: Author calculation.

Table 6. The comparison of empirical results from panel DOLS estimates tests.

Causal Relationship	Countries
FISHERY $\overset{\oplus}{\longleftrightarrow}$ GDP	Algeria, Argentina, Australia, Austria, Bangladesh, Belize, Bolivia., Burkina Faso, Canada, Central African, China, Congo, Costa Rica, Côte d'Ivoire, D. R. Congo, Denmark, Dominican Republic, Egypt, Finland, Germany, Ghana, Greece, Guatemala, Guinea-Bissau, Honduras, Iceland, India, Indonesia, Ireland, Israel, Italy, Jamaica, Liberia, Malaysia, Mali, Malta, Mexico, Nepal, Netherlands, New Zealand, Norway, Pakistan, Portugal, South Korea, St. Vincent, Sierra Leone, South Africa, Spain, Sri Lanka, Sudan, Swaziland, Sweden, Switzerland, Trinidad and Tobago, Tunisia, Turkey, United Kingdom, United States, Uruguay, Zambia. (22, DDCs and 60 DGCs)
FISHERY $\overset{\otimes}{\longleftrightarrow}$ GDP	Kiribati, Panama, Philippines,Rwanda, Senegal, Solomon Islands, Venezuela
GDP $\overset{\oplus}{\longrightarrow}$ FISHERY	France
GDP $\overset{\otimes}{\longrightarrow}$ FISHERY	Lesotho
FISHERY $\overset{\oplus}{\longrightarrow}$ GDP	Botswana, Colombia,Kenya,Morocco, Niger.

Notes: FISHERY $\overset{\oplus}{\longleftrightarrow}$ GDP denotes bi-directional positive impact between FISHERY and GDP, FISHERY $\overset{\otimes}{\longleftrightarrow}$GDP represents bi-directional negative impact between FISHERY and GDP.GDP $\overset{\oplus}{\longrightarrow}$FISHERY(GDP $\overset{\otimes}{\longrightarrow}$FISHERY) denotes positive (negative) impact running from GDP to FISHERY. FISHERY→ GDP denotes positive impact running from FISHERY to GDP.
Source: Author calculation.

$$\Delta FISHERY_{it} = \theta_{1j} + \lambda_{1i}ECM_{it-1} + \sum_{k}\theta_{11ik}\Delta GDP_{it-k} + \sum_{k}\theta_{12ik}\Delta FISHERY_{it-k} + \mu_{1it} \tag{8}$$

$$\Delta GDP_{it} = \theta_{2j} + \lambda_{2i}ECM_{it-1} + \sum_{k}\theta_{21ik}\Delta FISHERY_{it-k} + \sum_{k}\theta_{22ik}\Delta GDP_{it-k} + \mu_{2it} \tag{9}$$

where Δ denotes first differencing. We must use an instrument variables estimator to deal with the correlation between the error term and lagged dependent variables under the dynamic panel data model. During our examination procedure, we find that it is necessary to satisfy the classical assumptions on the error term when the lag length is 2, and, in turn, we use three and four periods as instruments for the lagged dependent variables. The sources of causation can be identified by testing for the significance of the coefficients of the dependent variables in equations (8) and (9). First, for short-term causality, we can test $H_0 : \theta_{12ik} = 0$ for all i and k in equation (8) or $H_0 : \theta_{21ik} = 0$ for all i and k in equation (9). Next, the long-term causality can be tested by looking at the significance of the speed of adjustment $\lambda_{1\mathrm{i}}$ and λ_{2i}, which are the coefficients of the ECM

Table 7. Panel causality test.

Dependent variable	Source of causation (independent variable)				
	Short-term		Lon-term		
	Δ FISHERY	Δ GDP	λ	λ/Δ FISHERY	λ/Δ GDP
Δ FISHERY	–	15.774**	−16.803**	–	316.084**
Δ GDP	2.517	–	3.559**	18.677**	–

Note: **indicates statistical significance at the 5% level.
Source: Author calculation.

terms. The significance of λ indicates the long-term relationship of the co-integrated process, and, therefore, movements along this path can be considered permanent. Next, the long-term causality can be tested by looking at the significance of the speed of adjustment λ_{1i} and λ_{2i}, which are the coefficients of the ECM terms. Finally, we can use the joint test to check for a strong causality test, where variables bear the burden of a short-term adjustment in order to re-establish a long-term equilibrium, following a shock to the system.[8] Because all variables enter the model in stationary form, a standard *F*-test can be used to test the null hypothesis, which shows that none of the estimated country-specific parameters are significant.[9]

Table 7 presents the results of a panel causality test between fishery and GDP. First, both coefficients of the ECMs (λ_{1i} and λ_{2i}) are statistically significant at the 5% level for FISHERY and GDP equations, providing further support for a clear long-term co-integration. Secondly, in the short-term, we display that there is a short-term causality flowing from GDP to fishery at the 5% level, suggesting uni-directional causality from income to fish consumption. However, the variable 'fishery' is statistically insignificant, although positive, at the 5% level in GDP equation, implying a lack of short-term

Table 8. Panel unit root tests for sub-sample countries.

		Level		First-difference	
Sub-samples	Statistics	Fishery	GDP	Δ Fishery	Δ GDP
DDC	LLC	−1.524	0.433	−12.704**	−9.379**
	IPS	0.408	−1.542	−17.365**	−12.385**
DGC	LLC	1.170	−0.116	−32.642**	−23.199**
	IPS	0.883	2.973	−29.415**	−28.282**
NHC	LLC	−0.989	−0.386	−41.313**	−22.280**
	IPS	−1.086	5.732	−40.783**	−27.138**
SHC	LLC	0.473	−1.261	−15.351**	−14.481**
	IPS	−0.110	0.334	−17.316**	−15.692**

Notes: Same as Table 2; LLC = Levin et al. (2002); IPS = Im et al. (2003).
** indicates statistical significance at the 5% level.
Source: Author calculation.

Table 9. Panel co-integration tests for sub-sample countries.

Dependent variable	Panel variance	Panel ρ	Panel PP	Panel ADF	Group ρ	Group PP	Group ADF
DDC							
FISHERY	4.322**	−6.446**	−6.412**	−6.338**	−4.321**	−6.226**	−5.766**
GDP	−2.325	−2.153**	−3.802**	−2.622**	−0.823	−3.248**	−1.543*
DGC							
FISHERY	3.364**	−5.271**	−5.570**	−3.623**	−4.971**	−6.518**	−4.146**
GDP	1.853**	−0.255	−1.642**	−1.285*	1.267	−1.338*	−0.410
NHC							
FISHERY	4.887**	−6.849**	−7.091**	−5.456**	−5.497**	−7.634**	−5.724**
GDP	−2.836	−1.585*	−3.644**	−2.478**	0.949	−2.014**	−0.766
SHC							
FISHERY	1.467*	−2.660**	−2.816**	−2.292**	−3.413**	−3.938**	−2.987**
GDP	−0.915	0.276	−0.144	−2.023**	0.050	−2.320**	−1.653**

Notes: Same as Table 3.
* rejects the null of no co-integration at the 10% level.
** rejects the null of no co-integration at the 5% level.
Source: Author calculation.

causality flowing from fishery to GDP. In the long-term, both fishery and GDP equations are significant at the 5% level, indicating a long-term bi-directional causality between two variables. Our results provide evidence that fish consumption and the level of income mutually influence each other in the long run, and fish is a common food.

3.2. The analysis of different groups

For a deeper investigation, we divide our full sample into DDC, DGC, SHC and NHC. We attempt to discover the broader effect of fish consumption on income, and vice versa, among different levels of economic–geography conditions. For example, there are generally accepted concepts of distinctions between the DDC and DGC, the former experiencing high levels of development. Also, the mid- and high-latitudes in the southern hemisphere have insufficient land, and, in turn, present a limited local market in contrast to the northern hemisphere (Bloom & Sachs, 1998). According to Bloom and Sachs (1998), businesses prefer to be situated in the northern hemisphere, rather than the southern hemisphere, so as to maximise benefits from the immediacy to market. Also, the mid-latitudes in the northern hemisphere are the most densely populated regions, and thus create an enormous market for innovation (Bloom & Sachs, 1998).

Table 8 exhibits the panel unit root results for each of the series for the sub-sample countries. According to Levin et al. (2002) and Im et al. (2003) test statistics, the variables GDP and 'fishery' exhibit unit root behaviour at least at the 5% significance level in the four sub-sample countries. Also, the results display the stationarity of the differencing variables in the four sub-sample countries, suggesting that the variables in the level form follow I (1) process. As before, we proceed to investigate the co-integrated relationship among GDP and fishery in the four sub-sample countries via Pedroni's (2004) panel co-integration test.

Table 9 displays the estimated results of the panel co-integration test for the four sub-sample countries. When the dependent variable is 'fishery', all test statistics significantly reject the null of no co-integration, providing strong support for a co-integrated relationship among the variables. However, the evidence of co-integration is relatively weak when the dependent variable is GDP, particularly for SHC where three test statistics are significant (Panel ADF, Group PP and Group ADF). Pedroni (2004) argued that the group statistics have better small sample properties than the other statistics. Following this line of reasoning, we conclude with a long-term co-integrated relationship between fishery and GDP in each sub-sample group. As in the full sample analysis, we employ a panel DOLS model to investigate the long-term impact between both two variables.

Table 10 provides the results of panel DOLS estimation for the four sub-sample countries. When the dependent variable is 'fishery', the estimated coefficient of GDP is positive and statistically significant at the 5% level in all sub-sample countries. Similarly, when the dependent variable is GDP, the variable 'fishery' is positive and statistically significant at the 5% level in all sub-sample countries. To conclude, the regional panel co-integration results provide clear support for the long-term co-integrated relationship between two variables in all sub-sample countries. As before, we next apply a panel ECM to examine the short- and long-term causalities and display the tests results in Table 11. Firstly, we demonstrate that there is a short- and long-term causality flowing from fishery to GDP in the DDC sample, indicating uni-directional causality from fishery consumption to aggregate income. Secondly, our findings reveal that GDP is statistically significant at the 10% and 5% level in the DGC and NHC samples,

Table 10. Panel DOLS estimates tests of co-integration for sub-sample countries.

	DDC	DGC	NHC	SHC
Dependent variable	*Independent variable is GDP*			
FISHERY	14.925**(35.695)	2.841**(27.453)	5.749**(40.590)	5.974**(9.118)
	Independent variable is Fishery			
GDP	0.066**(38.970)	0.081**(28.940)	0.089**(43.643)	0.046**(11.210)

Notes: Same as Table 4.
* rejects the null of no co-integration at the 10% level.
** rejects the null of no co-integration at the 5% level.
Source: Author calculation.

Table 11. Panel causality test for sub-sample countries.

1	Δ FISHERY	Δ GDP	λ	λ/Δ FISHERY	λ/Δ GDP
DDC					
Δ FISHERY	–	1.930	−1.305	–	3.876
Δ GDP	14.662**	–	2.644**	22.828**	–
DGC					
Δ FISHERY	–	28.317**	−1.789*	–	32.203**
Δ GDP	261.847**	–	−0.417	262.661**	–
NHC					
Δ FISHERY	–	26.711**	−2.699**	–	33.915**
Δ GDP	8.621*	–	1.001	10.209*	–
SHC					
Δ FISHERY	–	5.286	−3.011**	–	13.729**
Δ GDP	10.741**	–	1.827*	11.110**	–

Notes: Same as Table 7.
** indicates statistical significance at the 5% level.
Source: Author calculation.

providing strong support for short-term and long-term uni-directional causality from GDP to FISHERY, while the long-term causality ECM terms in insignificant in the GDP equation. We have discovered that the increase in income raises consumption of fishery in DGC and NHC. Hence, we provide policy recommendations to encourage supply of fishery in order to meet the demand of fishery in DGC and NHC. Finally, we find a long-term bi-directional causality between fishery and GDP in the SHC sample.

Overall, we obtain the critical policy implications. First, our results provide evidence that a bi-directional causality between fishery consumption and GDP exists in SHC in the long-term, which indicates that the level of income and fishery consumption mutually influence each other. This suggests that a high level of economic growth leads to a high level of fish consumption, and vice versa. Further, our findings reflect that changes in GDP and fish consumption per capita appear to be proportional, as in the case of China and Korea (Kim, 2010). We provide support that fish consumption and income are endogenous and, therefore, any single equation forecast of one or the other could be misleading. Furthermore, the governments in the SHC should explore channels in order to avoid the reduction in fish consumption during the period of falling aggregate income.

Second, we find that a uni-directional causality running from GDP to fishery consumption in DGC and NHC, suggesting that GDP serves as an engine of growth of fish consumption. That is, current and prior changes in GDP have significant impact on fishery. It follows that the decline in income could potentially hinder fishery consumption in the two group countries where this form of causality exists. Simultaneously, we are able to conclude that fish consumption has a relatively weak effect on national income in DGC and NHC.

Third, the results indicate a uni-directional causality running from fishery consumption to GDP in DDC, however, not for inverse direction. This means that continuous consumption of fish and a fishery product simultaneously generates a continuous rise in income and economic growth. In this case, our findings suggest that GDP is fundamentally driven by fishery produced. Beyond this, we reveal that a strategy for sustainable development with a higher level of fishery consumptions may, indeed, be appropriate in DDC. In addition, we show the presence of weak evidence flowing from GDP to fishery consumption. Hence, in a period of business cycle recession, it is not critically important for governments to over adjust fishery policies, provided that income fluctuations do not influence fishery consumption.

Finally, as a country attempts to estimate its demand for fishery products, it is necessary to identify the explanatory variables which affect the demand function of fishery consumption. We present strong evidence that income is an important determinant in explaining the changes in fishery consumption. For example, we display that the causality is flowing from national income to fish consumption in DGC and NHC, and, therefore, it is imperative that income is utilised as an explanatory variable to explain the demand function of fish consumption.

4. Conclusion

We investigate the long-term co-movement and the causal relationship between national income and fish consumption in a panel of 101 countries, covering the period of 1970–2006. In summary, our empirical results provide clear support for the positive long-term co-integrated relationship between GDP and fishery. In accordance with our empirical results, we attempt to offer possible policy implications/suggestions to those sample governments in promoting fishery policy.

Firstly, the presence of mutual causality between fishery consumption and GDP offers important implications for countries in SHC: governments should particularly emphasise the development of fishery industry to spur economic growth in SHC.

Secondly, the uni-directional causality flowing from GDP to fishery consumption suggests that the benefits of economic growth lead to a rise in consumption of fishery products in DGC and NHC. This is consistent with the experience of ‘food shortage’, particularly in China and India, where the expansion of economic growth instigated a significant increase in demand for meat and fish, and, in turn, resulted in shortage in many parts of the world. Therefore, the governments should establish ‘conservation, protection and persistence’ fishery policies to circumvent the occurrence of lack of supply in DGC and NHC.

Finally, uni-directional causality flowing from fishery consumption to GDP in DDC is due to ‘diminishing marginal utility’ of fishery consumption, given that fishery products are consumed more frequently in DDC. In the same context, the concept of ‘healthy eating’ is generally established in most households. We emphasise the importance of the development of fishery industries in DDC, provided that it has created rising opportunities for employment, thereby generating economic growth. Overall, we introduce this fundamental evidence for further research on fishery consumption, fishery industry and economic growth.

Notes

1. Fishery is used here in the broad sense to include fish and fishery products.
2. According to the definition proposed by The Food and Agriculture Organisation of the United Nations (FAO), the annual food supply per capita from fish and fishery products is defined as the quantity of both freshwater and marine fish, seafood and derived products available, per person, for human consumption over the course of that year.
3. For example, the tuna industry constitutes 61% of government revenue in Kiribati in 1998.
4. For the detailed statistics, we can see Pedroni (1999).
5. Our sample period depends on the availability of data.
6. FAO calculates this data by taking a country's fish production plus imports of fish and fishery products, minus exports, minus the amount of fishery production destined to non-food uses and plus or less variations in stocks.
7. The vector autoregressive (VAR) models may suggest a short-term relationship between the variables, because long-term information is removed in the first differencing, but the ECM model can avoid such shortcomings. In addition, ECM can identify sources of causation and can distinguish between a long- and a short-term relationship among the series which the usual Granger causality test cannot do. Moreover, the VAR method may be improper in the presence of co-integration.
8. See Asafu-Adjaye (2000) and Oh and Lee (2004).
9. Canning and Pedroni (1999), Azali et al. (2001), and Basu et al. (2003) provide a detailed discussion.

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