Journal of the Korea Academia-Industrial
cooperation Society
Vol. 18, No. 4 pp. 349-357, 2017

https://doi.org/10.5762/KAIS.2017.18.4.349
ISSN 1975-4701 / eISSN 2288-4688

Effects of Fisheries Technological Innovation on Growth per Capita across OECD Countries

Yoonsuk Lee[1], Jae Bong Chang[2*]
[1]**Fisheries Policy Research Division, Korea Maritime Institute,**
[2]**Department of Food Marketing and Safety, Konkuk University**

수산부문 기술혁신이 OECD 회원국의 성장률에 미친 효과

이윤숙[1], 장재봉[2*]
[1]한국해양수산개발원 수산연구본부, [2]건국대학교 식품유통공학과

Abstract The environmental problems affecting marine resources and slow growth in the fisheries industry is causing many countries to look for alternative inputs that can boost the fisheries sector. This study focuses on the effects of technological innovation in the fisheries industry on the gross domestic product (GDP) per capita across Organization for Economic Cooperation and Development (OECD) countries. Using a panel dataset, this study attempts to estimate the different effects of technological innovations in the fisheries industry from country to country using the differences-in-differences (DiD) method. After the DiD method, the Granger causality test is applied to determine the interactive relations between economic growth and the selected variables associated with technological innovation in the fisheries industry, such as government spending on fisheries R&D, the number of patents in fisheries, and employment. The results obtained from the DiD estimation show that government spending on fisheries R&D, fisheries technology development, and fisheries employment positively influences the GDP per capita across OECD counties. From the causality test, we found different bi-directional causal relationships between the GDP per capita and (spending) on fisheries technology development across countries.

요 약 최근 해양자원에 대한 환경적 제약에 대한 관심 증대와 다른 산업에 비해 상대적으로 뒤쳐진 수산부문의 성장으로 인해 많은 국가들은 수산부문의 다양한 성장 방안을 고려하고 추진하고 있다. 본 연구는 경제협력개발기구(OECD) 회원국들의 패널자료를 이용하여 수산부문의 기술혁신이 회원국 국민 1인당 국내총생산(GDP)에 미치는 영향을 분석하였다. 이를 위해 이중차분모형(DiD)과 Granger 인과성 검증방법을 이용하여 수산부문 연구개발(R&D) 지출, 특허, 고용 등의 수산부문 기술혁신과 경제 성장간의 상호 연관성과 파급효과를 분석하였다. 패널모형 분석에서는 24개 OECD 회원국들 가운데 수산부문의 기술개발 분야의 선도국가들인 노르웨이, 독일, 덴마크, 미국, 캐나다, 한국을 대상으로, 인과성 검증은 자료의 제약으로 OECD 회원국들 중에서 노르웨이, 미국, 캐나다, 한국만을 대상으로 국한하였다. 분석 결과, 수산부문에 대한 정부의 R&D 지출, 기술개발, 고용이 확대될수록 OECD 회원국들의 1인당 GDP는 증가하는 것으로 나타났다. 그러나, 이들 변수들 간의 상호연관성은 존재하지 않는 것으로 나타났다. 인과성 검증 결과, GDP와 수산부문 기술발전 사이의 인과성은 국가마다 상당한 차이를 보이는 것으로 나타났다.

Keywords : Differences-in-Differences (DiD); Fisheries Technological Innovation; GDP; Granger Causality test; Organization for Economic Cooperation and Development (OECD)

---

[*]Corresponding Author : Jae Bong Chang(Konkuk University)
Tel: +82-2-2049-6010 email: jbchang@konkuk.ac.kr

Received January 9, 2017 Revised March 7, 2017
Accepted April 7, 2017 Published April 30, 2017

1. Introduction

Many developed countries have tried to look for alternative inputs that can stimulate the growth and create new industries since they have faced to slow economic growth. Several literatures [1,2] reported that technological innovation is an essential determinant of economic growth in the long run, and showed[3] that technological innovation led to a rise in productivity growth in the United States during the 1990s. According to Romer growth model[4], technological innovation is created by research and development (R&D) utilizing human capital and knowledge stock[5]. R&D is defined as the process of creating new products, processes and technologies that can be used and marketed for mankind's benefits in the future[6]. Global competitiveness and sustainable growth put great stress on a key role of R&D into all industries sectors[7,8]. R&D catalyzes the invention and innovation, and its accumulation ultimately makes final products better and technology more advanced.

The R&D processes and their expenditures vary from industry to industry, from country to country and from year to year[6]. Several literatures[9,10]) investigated the heterogeneous effect of R&D spending on economic growth across different industries and countries. Such heterogenous effects of R&D are because the capacity to transfer and adapt technology is diverse according to the nature of industries and economy sizes. Our attention is focused on the impact of R&D on the primary sector, especially the fisheries sector and it's impact on different economic status of countries. We narrow all industrial sectors down to fisheries since several leading countries (EU countries, U.S., Japan, South Korea and etc.) emphasize a role of R&D on fisheries sector. Especially, EU countries, U.S. and Japan strongly regulate water pollution caused from fisheries activity and thus they make an effort to overcome this issue with technology applications[11]. Although it is important to differently treat aquaculture with capture fishery, this study aggregates aquaculture and capture fishery because the industrial size of each sector is small to be separate and is a lack of data information. In this paper, the word, fisheries, means a whole industry containing capture fishery and aquaculture.

Recently, in fisheries sector, a new technology trend appears to revitalize the industry in several countries such as Norway, Denmark, the United States, South Korea and so on. The new technology trend in fishery is achieved by combining fisheries sector and information and communication technology (ICT) sector, and such technology is referred to as ICT convergence. Technological innovation and market demand are driving the ICT sector toward convergence in fisheries sector[12]. In commercial capture fisheries, technology has been continuously introduced to strengthen the performance of fishing equipment in order to increase the value of fish caught, to decrease costs, to aid navigation, and to improve safety at sea[13]. Aquaculture has experienced biotechnology development for combating disease and epizootics, improving broodstock and feeding mechanisms[14]. Besides, water aqulity monitoring based on an ICT application to maintain water aqulity and to save energy. Such application of advanced technology in the fisheries sector has been taken the lead by government. Most R&D spending on fisheries sectors are supported through the indirect subsidies and the direct provision of a government. This is due to the limitation of fisheries sectors that is associated with the sustainable development of marine resources for future generations and food security. In addition, the paper[15] suggested that the social rate of return to R&D spending on some industrial sectors like a primary sector significantly exceeds the private rate of return.

There has been intensive interests and attempts[16,9] in empirically estimating the relationship between economic growth and R&D spending. Previous studies[7,17,18] presented a positive correlation between R&D spending and economic growth. Much of the R&D growth in an industry is driven by that county's economic growth, which can be measure by the gross domestic product (GDP) per capita.

Although many literature attempt to evaluate effects of R&D on economic growth, using various estimation techniques, it is still has empirical uncertainty about the magnitude of the productivity gains form R&D[19]. Such difficulty and restriction about measuring methods of R&D effects indubitably appear in this paper. In this study, we in this study select the government spending on R&D, the number of patents (technology development), employment as major inputs to bring technological innovation to fisheries sectors. With these selected variables, we investigate the empirical evidence of the effects of fisheries technological innovation on GDP per capita. There are many inputs such as human capital, knowledge accumulation, policy, R&D investments, advanced technology and so forth to encourage technological innovation in an industrial sector.

The major objective of this paper is to estimate the different effects of fisheries technological innovation on economic growth across countries and to determine interactive relations among the variables such as government spending on R&D expenditures, fisheries technology development, fisheries employment and economic growth across countries. With a panel dataset, the first method is to apply to the differences-in-differences (DiD hereafter) estimation by the two-way fixed effects panel model specifying both country- and time-effects. The DiD approaches are commonly used to estimate the effects of a policy change across different groups and different time[19,21,22]. The second method is to determine the causal relations among the selected variables, using Granger causality test.

2. Data

Panel dataset used in this paper consists of GDP per capita, government spending on fisheries R&D, the number of patents (fisheries technology development), and employment in fisheries. Such variables are collected from individual OECD country. The data series are selected for at least ten. The data sources are from the OECD website(https://stats.oecd.org/Index.aspx?DataSetCode=FISH_RD).

The government spending on fisheries R&D is the fisheries share of R&D expenditures on total government financial transfers. The R&D expenditures are categorized into business enterprises, government, foreign. However, this paper uses government expenditure due to features of fisheries sector.

In order to estimate Technology development, we use the number of patents. There are several ways to evaluate technology development in an industrial sector. Technology development can be measured by an practical aspect of outputs and qualitative aspects of academic fields. This paper considers the former approach for estimating fisheries technology development since qualitative approaches is ambiguous for counts[19]. Counting patents can be one of methods for measuring technological innovation because a patent is produced from the outputs of the inventive process. Although counting patents might not be the best approach to understand comprehensive technology development of a country, they can be relatively suited for identifying environmental innovation[23]. Employment in fishery counts all employment in various fisheries fields such as landings, aquaculture production, fleet, government financial transfers and so on.

We obtain 28 countries and 16 years' time period data from OECD website. The time series observations for each country are collected from 2000 to 2015. We discard 4 countries such as Czech Republic, Estonia, Hungary, Japan, and Slovak Republic because the numbers of an explanatory variable is not enough to estimate a panel regression model. Despite such first filtering, explanatory variables in some countries still have missing data. Thus, we use an unbalanced panel model. An unbalanced data does not matter to estimate a panel model. However, it matters to estimate Granger causality test. For the causality test, we again discard several countries to make dataset balanced. Nine countries; Canada, South Korea, Norway, the United States are estimated for Granger causality test.

3. Empirical Methodology

3.1 Panel Data Model

This paper focuses on estimating the linear relations between GDP per capita and the variables directly and indirectly related to R&D development such as government spending on fisheries R&D, the number of patents, and employment. The collected data show the typical characteristics of a panel data that include a large number of cross-sectional units and only a few periods[24]. Especially, explanatory variables in each country shows different years, referred as unbalanced panels. In order to deal with short and wide dataset, we consider a panel data model. There are various models to estimate panel data, but here we are interested in a DiD method that can be captured to estimate the impacts of technological innovation on economic growth across countries.

This study extends a general panel regression model to the two-way fixed-effects model suggested by [25]. Their method shows how to treat two group-specific effects in a regression model under an unbalanced data. Country-specific effects and time-specific effects are considered. The two-way fixed-effects model can be written by:

$$y_{i,t} = \gamma^{'} x_{i,t} + \alpha_i + \zeta_t + u_{i,t}$$

where $y_{i,t}$ represents GDP per capita at ith ($i = 1,\cdots,I$) of OECD countries in year t ($t = 1,\cdots,T$), $x_{i,t}$ is a vector of independent variables which includes fisheries R&D expenditures by government, the number of patents (Technology development in fisheries), and employment in fisheries, $\gamma^{'}$ is a k-vector of coefficients responding to independent variables ($k = 1,\cdots,K$), country-specific effects, α_i, and time-specific effects, ζ_t is countries-specific effects to be estimated, respectively. In the fixed effects model, the error term, $u_{i,t}$ is uncorrelated with independent variables, $E[u_{i,t}\,x_{i,t}, \alpha_i, \zeta_t] = 0$, and errors are not autocorrelated with each other, $cov(u_{i,s}, u_{i,t}) = 0$ if $i \neq j$ or $s \neq t$.

We concern either using a fixed effects model or a random effects, when dealing with a panel data. Finding the best approach for a panel data depends on the characteristics of data. With the collected data, we expect that each independent variable has a positive relation with GDP per capita, and such positive effects are similar across countries. In addition, we assume that country-specific effects and time-specific effects are correlated with the independent variables. The diagnostics for country and time-specific effects are performed by a poolability test. The null hypothesis of the poolability test is that there are no fixed effects in group and/ or time effects. The F test is expressed as [26];

$$F = \frac{(SSE_r - SSE_u)/q}{SSE_u/df_u} \sim F(q, df_u)$$

where SSE_r is the sum of squared residuals for the restricted model which is the fixed one-way model with country-specific effects or time-specific effects, and SSE_u is the sum of squared residuals for the two-way fixed model with countries and time series effects. $q = (I-1)k$ where I is the number of cross sections and k is the number of regressors except the constant. $df_u = n - k - I$ where n is the number of observation $n = I \times T$.

3.2 Granger Causal Relationship

Besides estimating DiD model, this paper performs Granger causal test for the interaction between theses variables. However, we face that time series are short. Three causality tests such as Granger test, Sims test, and the modified Sims are compared under small sample size[26]. Although these three causality tests are sensitive to sample size, the test with small sample size are significant. The Granger causality test is conducted with at least 10 years for each country. The causal test applied for this study using ordinary least squares (OLS) estimation[27];

$$X_2(t) = \alpha + \sum_{p=1}^{P} \alpha_p X_2(t-p) + \sum_{p=1}^{P} b_p X_1(t-p) + \beta t + \mu_t$$

The null hypothesis is that X_1 does not cause X_2, that is $H_0 : b_p = 0$ for $p = 1, \cdots, P$. The test statistic for the hypotheses of causal relationship is estimated by restricted $(b_j = 0)$ and unrestricted models. $X_2(t-p)$ presents a lagged dependent variable and determines autocorrelation with its own past. When we deal with a time series, it is important to treat lagged dependent variables as independent variables. In general, the current year's GDP per capita is affected by the last year's GDP per capita. For this causality test, it concerns how many lags of a dependent variable we need. The Akaike Information Criterion (AIC) found one lag for GDP per capita, but the lack of time series brings about difficulties to find the optimallags for other variables such as government spending on fisheries R&D, fisheries technology development, and employment in fisheries.

4. Results

4.1 Panel Data Model

We have particular interests in the different effects of fisheries technological innovation on GDP per capita across different countries since individual country has different level and capacity to adapt technology. GDP per capita as a responding variable, and fisheries R&D expenditures by government, the number of patents (fishery technology development), and employment in fisheries sector as independent variables are organized for a panel regression model. The collected panel data may have group-specific effect, time-specific effect, or both. We assume that the panel data used for this study has country- and time-specific effects to handle heterogeneity. Both effects are estimated by two-way fixed effects model.

In order to decide whether or not there are heterogenous effects of R&D across countries and time on the regression model, we conduct the poolability test, using F statistics. Table 1 presents the results of the poolability test. We reject the null hypothesis that there are no fixed effects in country and/or time and conclude that there are country- as well as time-specific effects with this data set.

Table 1. Test for Two-Way Fixed Effects

H_0: There are no fixed effects in group and/or time.
H_A: There are fixed effects in group and time.

F-value	P-value	Numerator	Denominator
115.87	<0.0001	37	107

In table 2, the estimates of the DiD by two-way fixed effects tell us whether any differences exist across countries and time periods. As for the regression parameters, the results present that fisheries R&D expenditures by government positively influence on GDP per capita, fisheries technology development has positive effects on GDP per capita, and employment in fisheries also positively affect GDP per capita. As a result, an increase by 1% in government spending on fisheries R&D raises GDP per capita by 0.0136%, an addition of one patent to fisheries sector lead to rise GDP per capita by 0.0161%. For employment in fisheries sector, an increase by a unit (1,000 persons) raises GDP per capita by 0.0038%, but we might carefully consider using the coefficient of employment because the value is not statistically significant. For country- and time-specific effects, CS_country represents cross-sectional effects of OECD 24 countries (drop Australia for dummy variable trap), and TS_2001~TS_2014 present time effects of the observations for each countries (drop 2000 year).

Table 2. Estimates of DiD by Two-Fixed Effects Model

Variable	Estimate	Standard Error	P-value
Intercept	10.4940	0.4528	<.0001
Fishery R&D expenditure	0.0136	0.0063	0.033
Fishery technology development	0.0161	0.0080	0.047
Fishery employment	0.0038	0.0407	0.925
CS_Canada	-0.0572	0.1860	0.759
CS_Denmark	-0.9566	0.0675	<.0001
CS_Germany	-0.2702	0.0396	<.0001
CS_South Korea	-0.2942	0.0435	<.0001
CS_Norway	-0.3839	0.0762	<.0001
CS_United States	-0.1775	0.0595	0.004
TS_2001	-0.4250	0.0583	<.0001
TS_2002	-0.3658	0.0577	<.0001
TS_2003	-0.3862	0.0434	<.0001
TS_2004	-0.3581	0.0400	<.0001
TS_2005	-0.3072	0.0377	<.0001
TS_2006	-0.2816	0.0360	<.0001
TS_2007	-0.2049	0.0356	<.0001
TS_2008	-0.1396	0.0356	0.000
TS_2009	-0.1254	0.0364	0.001
TS_2010	-0.1359	0.0360	0.000
TS_2011	-0.0902	0.0350	0.011
TS_2012	-0.0549	0.0356	0.126
TS_2013	-0.0458	0.0360	0.206
TS_2014	-0.0293	0.0365	0.424

This only reports the results from Canada, Denmark, Germany, South Korea, Norway, and United States among OECD 24 countries because they are the leading countries for fisheries technology development. For example, CS_South Korea presents an intercept of South Korea relative to the omitted country (Australia), and TS_2001 represents per GDP are lower than in 2015 by 0.425%. The cross-sectional effects are significant. Such results imply that the selected countries show the different effects of technological innovation in fisheries sector on economic growth. Most of the time effects are statistically significant.

4.2 Granger Causal Relationship

Although this panel regression model is useful, the model does not tell us the interactive relationship among the chosen variables. Thus, we supplement Granger causality tests for a pair of GDP per capita and government spending on fisheries R&D, a pair of government spending on fisheries R&D and fisheries technology development (the number of patents), a pair of GDP per capita and fisheries technology development, a pair of government spending on fisheries R&D and employment in fisheries, and a pair of fishery technology development and employment in individual country. Due to the data availability for estimation (require for at least 10 time series), Canada, South Korea, Norway, and United States are again selected for the causality test. As we mentioned earlier, we faced an issue to find an optimal lags of a dependent variable. Thus if there exist difficulties to find the optimal lags of a dependent variable in each country, we create one lag of a dependent variable and add it to independent variables.

Canada: There is a bidirectional relationship between GDP per capital and fisheries technology development. Fisheries technology development is affected by government spending on fisheries R&D, but not vice versa. For a pair of GDP per capita and government spending on fisheries R&D, government spending on fisheries R&D cause GDP per capita. There are no causal relationship between government spending on fisheries R&D and employment in fisheries, and between fisheries technology development and employment in fisheries.

South Korea: This country shows relatively higher number of patents (technology development) in fisheries than other countries (average 187/per year). Such many numbers of patents affect GDP per capita. Except for this relationship, however, we could not find any causal relationship between other variables.

Norway: Fisheries technology development affects government spending on fisheries R&D, but not vice versa. GDP per capita cause government spending on fisheries R&D, but not vice versa. The government spending on fisheries R&D and the number of patents do not have any relationship of employment in fisheries, respectively. Surprisingly, we did not find a close relationship between fisheries technological innovation and economic growth in Norway that symbolizing the most advanced technology innovation in fisheries.

The United States: The employment variableis discarded since observations are not enough to test Granger causality. Fisheries technology development influence on GDP per capita, but not vice versa. There is no causal relationship between GDP per capita and fisheries R&D expenditures, and between fisheries R&D expenditures and fisheries technology development.

The results from Granger causality tests show there exist a causal relationship between some of variables, however causal relations of others are insufficient. With several countries, we could carefully suggest that fisheries technology development (the number of patents) causes GDP per capita.

Table 3. Causal Relationship among Variables according to Selected Countries

Countries	Variables	Causal Direction	Variables
Canada	GDP per capita	→ ←	Fisheries Technology Development
	Fishery R&D Expenditure	→ ×	Fisheries Technology Development
	GDP per capita	× →	Fisheries R&D Expenditure
	Fishery R&D Expenditure	× ×	Fisheries Employment
	Fishery Technology Development	× ×	Fisheries Employment
Korea (South)	GDP per capita	× ←	Fishery Technology Development
	Fishery R&D Expenditure	× ×	Fishery Technology Development
	GDP per capita	× ×	Fishery R&D Expenditure
	Fishery R&D Expenditure	× ×	Fishery Employment
	Fishery Technology Development	× ×	Fishery Employment
Norway	GDP per capita	× ×	Fishery Technology Development
	Fishery R&D Expenditure	× ←	Fishery Technology Development
	GDP per capita	→ ×	Fishery R&D Expenditure
	Fishery R&D Expenditure	× ×	Fishery Employment
	Fishery Technology Development	× ×	Fishery Employment
United States	GDP per capita	× ←	Fishery Technology Development
	GDP per capita	× ×	Fishery R&D Expenditure
	Fishery R&D Expenditure	× ×	Fishery Technology Development

Note: variable 1 → variable 2 mean that variable 2 affects variable 1, or variable 1 is influenced by variable. "×" represents no causal relationship between variables.

5. Conclusions

Currently, almost all industrial sectors emphasize technological advance in order to boost economic growth. In this paper, we have an interest in estimating the different impact of R&D creating technological movement in fisheries sector on the growth per capita across different countries. The available data of fisheries R&D expenditure by government, technology development (the number of patents), employment in fisheries sector, and GDP per capita across OECD countries are estimated with the two-way fixed effect model and Granger causality test.

From the panel data model, government spending on fisheries R&D, fisheries technology development, and fisheries employment positively influence GDP per capita across the countries. The results from the panel data model cannot show the interactive relations among the variables. Granger causality test is conducted to obtain further information among variables. From the causality test, we imply government spending on fisheries R&D and fishery technology development do not encourage to a country to hire more employees in fisheries sector. It can bring certain concerns that technology development ironically reduce employees. However, from the causality results, we must not jump to the conclusion that there are no close relationships among fisheries technological innovation and economic growth. The limited data information of each variables may mislead to insufficient causal relationship between GDP per capita and fisheries R&D expenditure, fisheries technology development, fisheries employment across countries.The environmental problems affecting marine resources and slow growth in the fisheries industry is causing many countries to look for alternative inputs that can boost the fisheries sector. This study focuses on the effects of technological innovation in the fisheries industry on the gross domestic product (GDP) per capita across Organization for Economic Cooperation and Development (OECD) countries. Using a panel dataset, this study attempts to estimate the different effects of technological innovations in the fisheries industry from country to country using the differences-in-differences (DiD) method. After the DiD method, the Granger causality test is applied to determine the interactive relations between economic growth and the selected variables associated with technological innovation in the fisheries industry, such as government spending on fisheries R&D, the number of patents in fisheries, and employment. The results obtained from the DiD estimation show that government spending on fisheries R&D, fisheries technology development, and fisheries employment positively influences the GDP per capita across OECD counties. From the causality test, we found different bi-directional causal relationships between the GDP per capita and (spending?) on fisheries technology development across countries.

In this study, we find major implications. The fishery sector in some countries might not enjoy cost reduction from technology development because of high operating cost of high-tech equipment, while other countries already experienced the benefits from technological innovation. There are literatures suggesting various aspects and measures of the impacts of technological innovations on economic growth. Some literatures found that the direct funds of a government into R&D did not increase inventive activity because the government spending on R&D mostly raised the wages of scientists, engineers and so on[15]. Others also suggested the negative and positive factors influencing economic growth. The surplus appropriability problem and knowledge spillovers discourage investment in R&D, and creative destruction and duplication externalities encourage overinvestment in R&D[2]. Their means of the surplus appropriability problem is that innovators in a decentralized economy are not able to decide the entire consumer surplus for the good that they create.

This paper still remains questions about 1) how technological innovation helps to determine the optimal allocation of fisheries resources 2) the spillover effects of fisheries technology innovation between developed countries and developing countries 3) direct relationship between technology development and productivity in fisheries(or aquaculture).

References

[1] Jeffrey, D. S., McArthur, J. W., Technological Advance and Long-Term Economic Growth in Asia, Bai, C-E., Yuen, C-W. Eds., MIT Press, Cambridge, pp. 157-185, 2002.

[2] Jones. C. I., Williams, J.C. “Too much of a Good Thing: The Economics of Investment in R&D,” *Journal of Economic Growth* 5, pp. 65-85, 2000.
DOI: https://doi.org/10.1023/A:1009826304308

[3] Basu, S., Fernald, J. G., Shapiro, M.D. Productivity Growth in the 1990s: Technology, Utilization, or Adjustment? Carnegie-Rochester Conference Series on Public Policy, pp. 117-165, Jan. 2001.
DOI: https://doi.org/10.1016/S0167-2231(01)00054-9

[4] Romer, P. M., "Increasing Returns and Long-Run Growth," Journal of Political Economy 94, pp. 1002-1037, 1986.
DOI: https://doi.org/10.1086/261420

[5] Ulku, H. R&D, Innovation, and Economic Growth: An Empirical Analysis. IMF Working paper, 2004.

[6] IRI. 2016 Global R&D Funding Forecast, ABM Science Group 11, New Jersey, 2015.

[7] Blackburn, K., Hung, V.T.Y., Pozzolo, A.F. “Research, Development, and Human Capital Accumulation,” *Journal of Monetary Economics* 22, pp. 189-206, 2000.
DOI: https://doi.org/10.1016/s0164-0704(00)00128-2

[8] Akcali, B. Y., Sismanoglu, E., “Innovation and the Effect of Research and Development (R&D) Expenditure on Growth in Some Developing and Developed Countries,” *Social and Behavioral Science* 195, pp. 768-775, 2015.
DOI: https://doi.org/10.1016/j.sbspro.2015.06.474

[9] Wang, D. H-M., Yu, T.H-K., Liu, H-Q., “Heterogeneous Effect of High-Tech Industrial R&D Spending on Economic Growth,” *Journal of Business Research* 66, pp. 1990-1993, 2013.

DOI: https://doi.org/10.1016/j.jbusres.2013.02.023

[10] Greenhalgh, C., Longland, M., Bosworth, D. "Technological Activity and Employment in a Panel of UK Firms," *Scottish Journal of Political Economy* 48, pp. 260-282, 2001.
DOI: https://doi.org/10.1111/1467-9485.00198

[11] Standal, D. "Nut and Bolts in Fishereis Management-a Technological Approach to Sustainable Fisheries?" *Marine Policy* 29, pp. 255-263, 2005.
DOI: https://doi.org/10.1016/j.marpol.2004.04.004

[12] Singh, R. and S. Raja. "Convergence in Information and Communication Technology: Strategic and Regulatory Considerations," The World Bank, Washington, DC, 2010.
DOI: https://doi.org/10.1596/978-0-8213-8169-4

[13] Ritzau, E. O., Paul, M., Henrik, G., Adriaan, D.R. "Technological Development and Fisheries Management," *Reviews in Fisheries Science & Aquaculture* 22, pp. 156-174, 2014.
DOI: https://doi.org/10.1080/23308249.2014.899557

[14] Burnell, G., Allan, G. New Technologies in Aquaculture: Improving Production Efficiency, Quality and Environmental Management, Elsevier, Amsterdam, 2009.
DOI: https://doi.org/10.1533/9781845696474

[15] Goolsbee, A. Does Government R&D Policy mainly Benefit Scientists and Engineers? NBER Working Paper Series. 1998.

[16] Leonard, S. J. Technological Change and the Extent of Frictional and Structural Unemployment. Working paper series, Institute for Research on Labor and Employment, UC Berkeley, 1986.

[17] Guloglu, B., Tekin, R. B. A, "Panel Causality Analysis of the Relationship among Research and Development, Innovation, and Economic Growth in High-Income OECD Countries," *Eurasian Economic Review* 2, pp. 32-47, 2012.

[18] Hu, G. A., "Innovation and Economic Growth in East Asia: An Overview," *Asian Economic Policy Review* 10, pp. 19-37, 2015.
DOI: https://doi.org/10.1111/aepr.12078

[19] Parham, Dean "Empirical Analysis of the Effects of R&D on Productivity: Implications for Productivity Measurement?" OECD Workshop on Productivity Measurement and Analysis, Bern, Switzerland 16-18 October, 2006.

[20] Card, D., Krueger, B. A., "Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania," *The American Economic Review* 84, pp. 772-793, 1994.

[21] Author, H.D. "Outsourcing at Will: Unjust Dismissal Doctrine and the Growth of Temporary Help Employment," *Journal of Labor Economics* 21, pp. 1-42, 2009.

[22] Lechner, M., Fodriguez, N., Fernandez, D. Difference-in-Differences Estimation by FE and OLS when There is Panel Non-Response. IZA Discussion Papers No. 9490, 2015.

[23] OECD report, Measuring Environmental Innovation Using Patent Data: Policy Relevance. http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/EPOC/WPEI(2014)6/FINAL&docLanguage=En 2015; Accessed 2016.7.21.

[24] Greene, H. William. Econometric Analysis Fifth ed; Prentice Hall, New Jersey. 2003.

[25] Wansbeek, T., Kapteyn, A. "Estimation of the Error-Component Model with Incomplete Panels," *Journal of Econometrics* 41, pp. 341-361, 1989.
DOI: https://doi.org/10.1016/0304-4076(89)90066-3

[26] Moulton, R. B., "Diagnostics for Group Effects in Regression Analysis," *Journal of Business and Economic Statistics* 2, pp. 275-282, 1987.
DOI: https://doi.org/10.2307/1391908

[27] Guilkey, D. K. Salemi, M. K., "Small Sample Properties of Three Tests for Granger-Causal Ordering in a Bivariate Stochastic System," *The Review of Economics and Statistics* 64, pp. 558-680, 1982.
DOI: https://doi.org/10.2307/1923951

Yoonsuk Lee [Regular member]

- May. 2009 : Oklahoma State Univ., U.S.A, MS
- May. 2013 : Oklahoma State Univ., U.S.A, PhD
- June. 2013 ~ July. 2014 : University of Arkansas at Pine Bluff, Aquaculture and Fisheries Dept., Associate Researcher
- Nov. 2014 ~ current : Korea Maritime Institute, Fisheries Research Division, Senior Researcher

<Research Interests>
Applied Economics, Econometrics

Jae Bong Chang [Regular member]

- Feb. 2001 : Seoul National Univ., Economics, MS
- May. 2009 : Oklahoma State Univ., U.S.A., Agricultrual Economics, PhD
- March 2012 ~ Feb. 2017 : Yeungnam Univ., Dept. of Food and Resource Economics, Associate Professor
- March 2017 ~ current : Konkuk Univ., Dept. of Food Marketing and Safety, Assistant Professor

<Research Interests>
Food and Consumer Economics, Agricultural Economics